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Founded 1871

A Journal of Scottish Natural History

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With which is incorporated *The Annals of Scottish Natural History*
and *The Western Naturalist*

110th Year 1998

CONTENTS

1998 - Part 2

The Feeding Ecology of some *Bombus* and *Psithyrus* Bumble-Bees (Hym., Apidae) in Northern Scotland
By Dr. Murdo A. Macdonald 51-104

Exceptionally Large Fox at Fintry, West Stirlingshire
By Mr. John Mitchell 105-106

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THE FEEDING ECOLOGY OF SOME *Bombus* AND *Psithyrus* BUMBLE-BEES (Hym., Apidae) IN NORTHERN SCOTLAND

By MURDO A. MACDONALD
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Introduction

Observations of bumble-bees (*Bombus* and *Psithyrus*) in north and west Scotland since 1988 led me to suspect that an important factor restricting the distribution and abundance of the commoner and more widespread bees was the shortage of native forage species, especially early and late in the season. This is an old idea, lying behind some of the ideas for increasing the numbers of bee colonies reviewed by Free and Butler (1959), while Owen and Owen (1975) have identified the importance of gardens to three groups of insects (not bees) without considering in detail the potential of exotic forage in expanding ecological opportunity. In the Scottish context, the importance of exotic garden flowers has been expressed succinctly by Brian (1957), who described a garden in her west Scotland study area as "an oasis in May and June surrounded by a desert of flowerless arable fields and moorland".

In order to try to understand the relative importance of native and exotic forage plants to the five most common species at one locality in northern Scotland, I attempted to describe the diet and general feeding ecology of *Bombus lucorum* (L.), *B. pratorum* (L.), *B. hortorum* (L.), *B. pascuorum* (Scop.) and *Psithyrus bohemicus* (Seidl) throughout the season of 1997. (Bee names follow Prys-Jones and Corbet, 1987). This had the added interest of describing in some detail the feeding ecology of these insects farther north in Britain than has been done before in an area with a relatively poor bumble-bee fauna, thus giving opportunities for comparisons with studies elsewhere. The time available for field work on most days was very limited. As a result, many obvious routes of inquiry could not be followed in 1997, but might be taken up in future.

Throughout this paper, native and naturalised plant species are included together. Exotic species are regarded as those found in the study area exclusively as a result of deliberate cultivation or immediate escape from that. Appendix 2 gives the English names of all forage plants mentioned in the text.

METHODS

The Study Areas

STRATHPEFFER

The principal observations were carried out in the area immediately surrounding my 0.18 ha garden on the edge of the village of Strathpeffer, Highland Region (57° 35' N, NH 478575, altitude 107 m). The area included the garden itself, which contains a wide variety of garden plants as well as substantial wild areas containing a wide range of native species. Many invasive species were tolerated or even encouraged, and pesticides were used only rarely, and then in small and limited applications. On one side the garden bounds a Forestry Commission property which, although containing exotic softwood species, comprised in its closest parts a mixture of native and naturalised trees (especially *Alnus glutinosa*, *Acer pseudoplatanus*, and *Salix caprea*), and more open scrubby areas supporting a diverse ground and shrub layer of mostly native and naturalised species.

The remaining habitats were dominated by farmland (principally grazing for sheep and cattle) and the associated ruderal habitats, but included also hedges, wild field edges, lochside vegetation, and gardens, all of which provided important forage for the bees.

The climate from March to October (the bumble-bee season) at Strathpeffer is described in terms of rainfall and temperature in Figure 1. I did not collect this data under strict Meteorological Office protocols, but they serve to give a general picture of conditions in 1997. Mean annual rainfall 1989-97 was 942 mm (range 657-1268 mm). Summer weather in 1997 was generally typical of recent years, though May and June were unusually wet, and August to October unusually dry. The first autumn ground frost was on 16th September, and the first air frost on 20th October. Advice to gardeners (Hay, 1982) is that spring planting begins two weeks later, and summer ends four weeks earlier than in southern England. This short season may be compensated somewhat by the longer summer days - an extra 1.5 hours sunrise to sunset in June compared with London (Meteorological Office, 1989).

COIGACH

I was able to make occasional unsystematic observations, continuing into 1998, around Achnahaird in Coigach on the west coast of Scotland (58° 03' N, NB 91 and NC 01, altitude 0-50 m, 75 km N.W. of Strathpeffer) for comparison with the situation in the east. This area is typical of much of the north-west of Scotland:

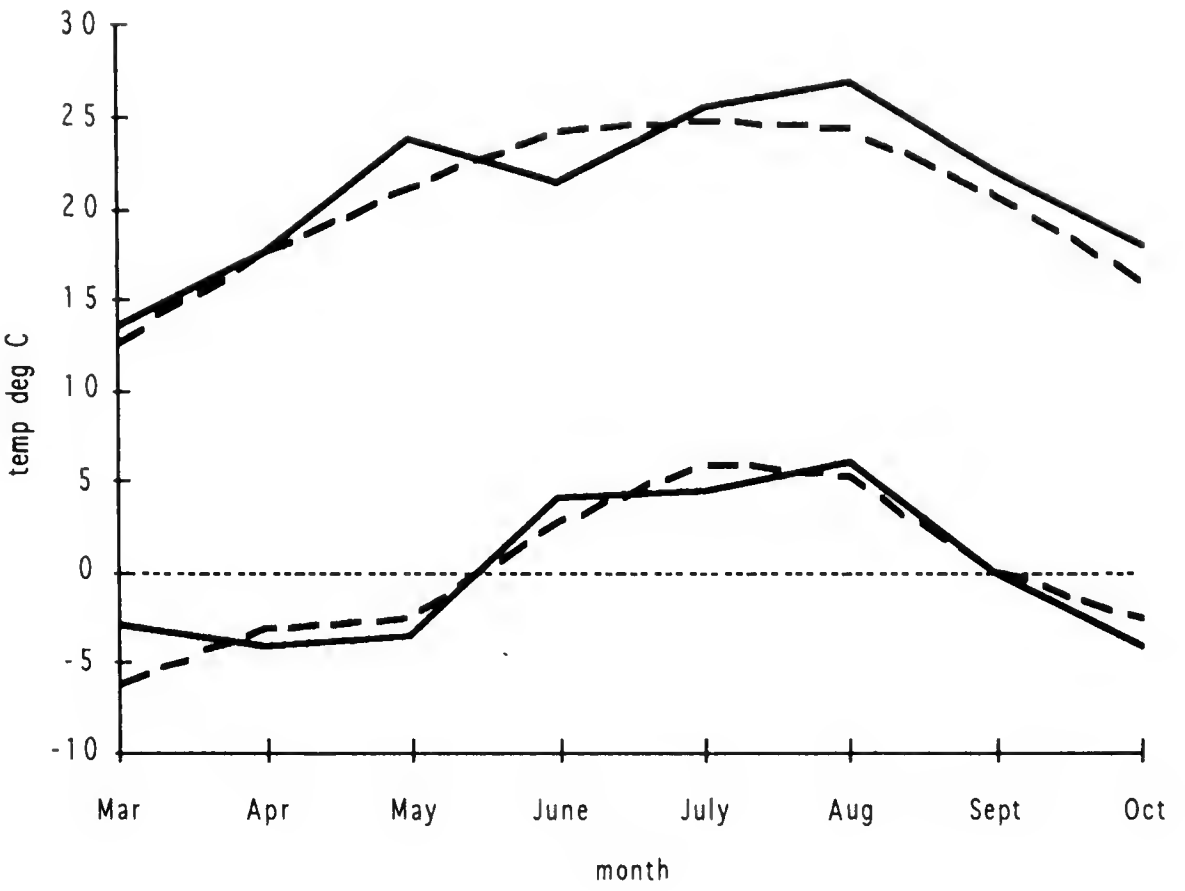


Figure 1

Weather at Strathpeffer, March - October 1997

A: Maximum and minimum temperatures (solid lines) and average values 1991-97 (broken lines).

B: Rainfall (black bars), and average values 1989-97 (white bars).

small villages with croft lands (smallholdings) scattered around the coast, and inland habitats dominated by acid heather moorland. For social, cultural and environmental reasons (edaphic, climatic, and the abundance of biting midges *Culicoides*) gardens are generally less diverse in plants than in the east, with low-maintenance shrubs (*Salix, Hebe*, *Fuchsia magellanica*) and perennials like *Lupinus* and *Crocosmia* common. The west coast generally has a milder wetter climate than the east, with an earlier spring, though the climate around Achnahaird is much affected by local geographical factors (it lies at the end of a long low peninsula) and is probably drier than the 1200-1300 mm annual rainfall which general data for the area suggest.

Also, on 26th May I had the opportunity to record the native entomophilous plants in flower during a 120-km car journey from Strathpeffer to Fort William (NN 17), traversing a good cross-section of terrestrial habitats in the Highlands. Most recording was done from the car, so some less conspicuous species would have been overlooked, but these are unlikely to have been favoured by bees. Casual observations from other parts of the Highland Region were made whenever the opportunity arose, but these are not included in the detailed analyses.

THE BEE FAUNAS

Apart from the five species considered in this present study, the following bumble-bees were recorded at Strathpeffer in 1997, all irregularly or in small numbers: *B. soroeensis* (Fabr.), *B. magnus* Kruger, *B. terrestris* (L.), *B. lapidarius* (L.) and *P. sylvestris* (Lepeletier). In previous years (1988-96) I have recorded *B. monticola* Smith, *B. jonellus* (Kirby) and *P. campestris* (Panzer), again irregularly. Only *B. lucorum* suffered significantly from the attentions of cuckoo bumble-bees, *Psithyrus bohemicus* being the only brood parasite present in numbers, and this should be borne in mind when interpreting the results for *lucorum*. The only bees I recorded in Coigach during six years were *B. lucorum, B. magnus, B. hortorum, B. pascuorum, B. muscorum* (L.) and *B. jonellus. B. soroeensis* and *P. bohemicus* were recorded there for the first time in 1998.

Recording

Daily observations were made at Strathpeffer in 1997 from 20th March (when the first *Bombus* was seen) to 15th October (when the last *pascuorum* was active, and *lucorum* had not been seen for six days), except for 16 days when I was out of the area. This covered 194 of a possible 210 days in the season, and on all but ten days, mostly in the first few weeks, some bee activity was recorded. Additional observations were made from 13th March (first *Bombus* seen) to 10th April 1998 (three days after *Salix caprea* catkins had finished), specifically to record the use

made of *Salix* which was in short supply the previous year. I aimed to sample all the potential forage plant species occurring within about 1.0 km radius of my garden on each day during a representative walk. Individual forage species were examined in the full range of habitats in which they occurred, in case habitat affected their attractiveness to the bees. Inevitably, some rare or rarely-used plants, and those at the extreme ends of their flowering seasons, will have been missed, but such errors are unlikely to have a significant effect on the overall picture. It was impractical to visit other private gardens daily, so I used my own for records of exotic species.

For practical reasons the walk could not be standardised in terms of time of day. Activity of bees was not consistently affected by time of day. No numeric data were collected on this, but diurnal patterns of activity were highly variable and unpredictable from one day to the next. Other factors, notably the weather conditions, were clearly of far greater importance. Route, duration and distance depended on bee activity and forage used. At the beginning of the season, when forage plants were confined to the garden and its immediate surroundings, all recording could sometimes be complete in 15 minutes. At the height of the season in July and August, the walk covered some 4.0 km and took up to 1.5 hours. The total area surveyed during the year at Strathpeffer was approximately 5.0 ha. Binoculars were used to locate and identify bees foraging in tree tops and other inaccessible places. Whenever possible, walks were undertaken in the most clement weather of the day. Recording within each 10-day block covered the period from 1.0-4.0 hours after sunrise to a similar interval before sunset.

Records used for analysis were of a bee species (divided as sex and caste) on a forage plant on one day. On each day, I recorded the sex and caste of all bee species active; the species on which they were foraging; whether there was pollen in the corbiculum, or whether the bee was actively gathering pollen; and the height at which the first been seen (of each species and sex separately) was foraging on each plant species. If I was able to determine that no successful foraging had occurred, no record was made. This happened only rarely, however, as it was difficult to determine if probing at a flower was productive, and some of the plants recorded may not have provided any sustenance. No attempt was made to count numbers of bees, nor to estimate relative numbers. I found this impossible to do in a way which would describe seasonal variations reliably, given the variations in forage area through the season, and the difficulties of counting in such diverse situations as tree-tops, dense thickets, at large tubular flowers (into which bees frequently disappeared completely), and low open herbage. I also found it impossible easily to count the sexes and castes separately, even in ideal conditions.

The implications of this approach must be understood. The probability of recording a bee on a particular plant is dependent on several factors, including forage plant attractiveness, its food value, its density, the availability of alternatives, the number of bees active, and differences in behaviour of different sexes and at different phases in the cycle. One bee feeding on one plant species would constitute one record, as would many bees feeding on a different species. This method could potentially give misleading results. For example, if a single individual had a preference for unusual forage and was frequently recorded, that plant would be over-represented in the data. I do not believe that bias from this source was significant, but the patterns of activity and use of forage plants derived from these data are not necessarily correlated with numbers of bees other than (in some cases only) in rank order. Nor do the results indicate anything about relative food values or absolute preferences, since rewards and flower densities were not assessed.

All data refer to general populations. No bees were marked, so were not known as individuals, nor as belonging to a particular colony.

Identification

Identification of species, sex and caste was done entirely in the field. In most cases there was no difficulty with identification of the species, but some uncertainty must attach to *B. lucorum* where confusion with worker and male *magnus* is possible. At least two queens of *magnus* were foraging on *Ulex europaeus* in the study area during June. In addition, some queens and males showed characters of the continental *B. cryptarum* (F.), thought by some to occur also in Britain. All bees in this group not showing the characters of *magnus* were classed as *lucorum*. *B. terrestris* has never been proved to breed locally, though queens have occurred intermittently over the years and one queen was present in late September and early October 1997. It is possible, but unlikely, that a small number of *magnus* and *terrestris* workers or males may have been recorded as *lucorum*.

The separation of queens and workers was (in all except *B. pratorum* whose queens and workers differ in pelage characters) based on size and was somewhat subjective, especially in the case of *hortorum* and *pascuorum* where the overlap in size is considerable. In these species (perhaps especially *hortorum*) small queens and large workers will sometimes have been mis-classified. Males generally gave no problems but doubtful individuals of *B. hortorum*, *B. pascuorum* and *P. bohemicus*, and dark morphs of *lucorum*, were frequently caught in a small clear plastic box to allow a view of the abdominal tip, the shape of which I found the simplest way to separate males from females.

Native plants were identified to the species in all but a few difficult aggregates. Names used follow Stace (1991). Exotic species were identified from Stace where possible, and otherwise from a variety of published and unpublished sources. In some cases identification was not possible beyond the genus. In all cases the lowest taxon determined was used for analysis, except for the two very similar species *Pulmonaria officinalis* and *P. rubra*, which were growing intermixed and treated by both me and the bees as a single form. Because no single authority was used for horticultural nomenclature, there may be slight inconsistency in the names applied to some exotic plants.

Analysis

The observations from blocks of 10 consecutive days from 20th March (Appendix 1) were summed for analysis, numbers of records being scaled up proportionately when days were missed in any one block. Many forage plants were recorded only once in any block for a bee species. Some of these plants were rare in the area. Others clearly appeared in the lists as a result of sampling of new food sources (Heinrich, 1976) as individual bees were seen obviously trying with little or no success to feed at flowers; for example a worker *pratorum* at *Digitalis purpurea*, and a queen *lucorum* at *Lonicera periclymenum*, while a worker *pascuorum* was observed investigating the white fruits of *Symphoricarpos albus*.

An attempt to exclude such records was made by removing from detailed analyses, for a particular bee, plants which both:

(a) never scored more than one record/block, and

(b) never contributed more than 10% of records in any block.

A plant meeting this criterion for one sex only, was nevertheless included for both. The species retained are called 'core forage species'. The criterion for exclusion is arbitrary, but excludes from the detailed analyses many (almost certainly not all) plants which were irrelevant to the overall feeding ecology of the bumble-bees. *Dactylorhiza purpurella*, recorded for *P. bohemicus*, was excluded since it has no nectar and does not provide edible pollen.

Breadth of diet was calculated using the method of Levins (1968). This gives an index which varies from 1.0 to N, where N is the number of species in the sample. Overlap in diet was estimated by the index given by Horn (1966). Overlap calculations necessarily included some records of non-core forage species in cases where a plant was core for one bee, but not for the other in the comparison.

RESULTS

Availability of Wild Forage in the Highlands

Use of exotic forage might not by itself indicate a requirement for such plants, but rather a preference for exotic over available native species. On 26th May, two months after the first bee had emerged at Strathpeffer, on a 120-km car journey through the Highlands, 27 native species were recorded in flower. Flowers of ten of these were rare because the plants were at the extreme ends of their flowering seasons.

Those classed as abundant were: *Anthriscus sylvestris*°, *Bellis perennis*°, *Cytisus scoparius**, *Ranunculus acris*°, *R. repens*°, *Stellaria holostea*° (possibly also S. *graminea*°), *Taraxacum vulgaris* agg.* and *Ulex europaeus**. Locally common were: *Acer pseudoplatanus**, *Aesculus hippocastanum**, *Cardamine pratensis*°, *Crataegus monogyna*°, *Hyacinthoides non-scripta*, *Primula vulgaris*°, *Prunus padus*°, *Sorbus aucuparia*° and *Viola riviniana*°. Rare were: *Achillea millefolium*°, *Alliaria petiolata*, *Anemone nemorosa*°, *Lamium purpureum**, *Lotus corniculatus*, *Oxalis acetosella*°, *Prunus avium**, *Rhododendron ponticum** (naturalised in the west Highlands), *Salix ?aurita* and *Silene latifolia*°.

Only those eight asterisked were recorded as core forage species during this study, including two pollen species used only by *B. lucorum*, and three trees used only by *lucorum* and *pratorum*. Those marked ° were present in the main study area and never recorded as used by any bumble-bee. This relative scarcity of appropriate native forage over a large area mirrored in general the situation in Strathpeffer at the same time when the only additional native forage recorded was *Vicia sepium* (a single record for *B. pascuorum*). This indicates that the bees most likely to suffer from a lack of native forage in spring are the two long-tongued species *B. hortorum* and *B. pascuorum* and possibly also *P. bohemicus*.

In Coigach between 23rd May and 1st June only 16 native species were in bloom, only six of which were recorded as bee forage. Of these, four were very scarce. Even at the end of June only 21 entomophilous species were flowering, 11 of which were not known as bee forage. Five of the remaining 10 species were scarce, leaving *Erica cinerea*, *E. tetralix*, *Potentilla erecta*, *Thymus polytrichus* and *Trifolium repens* as common potential native forage species. As most plants of these species occurred in open exposed habitats (moorland and heavily grazed coastal machair) their value to *B. hortorum* and *B. pascuorum*, which tend to avoid such habitats, was further limited.

Table 1

Summary of Seasons of the Bees at Strathpeffer in 1997

Entries in brackets give data from Cambridge, 1977-78,
in S.E. England (Prys-Jones, 1982).

Species	*B. lucorum*	*B. pratorum*	*B. hortorum*	*B. pascuorum*	*P. bohemicus*
First queen	20/3	23/3	13/4	26/4	15/4
First worker	11/5	10/5	28/5	10/6	--
Days to 1st worker from 1st queen	*52 (56-100)*	*48 (39-61)*	*45 (31-59)*	*45 (37-45)*	--
First male	6/7	22/6	13/7	30/7	4/7
Days to 1st male from 1st queen	*108 (84-113)*	*91 (80-90)*	*91 (53-59)*	*95 (87-103)*	*80*
Days to 1st male from 1st worker	*56 (13-28)*	*43 (19-51)*	*46 (0-22)*	*50 (50-58)*	--
Last queen	6/10	8/8	4/10	11/10	29/8
Last worker	9/10	7/9	26/8	15/10	--
Last male	8/10	11/9	9/9	13/10	16/9
Workers active (days)	*152 (91-121)*	*121 (138-154)*	*91 (102-132)*	*128 (135-155)*	--
Full season (days)	*204 (186-202)*	*173 (185-215)*	*175 (166-170)*	*173 (172-200)*	*155*

During July and August the situation changed markedly, with abundant native forage widely available and used by all species. By 4th September (end of block 17) most of the native forage at Strathpeffer had disappeared, with only eight species available, some of which appeared to offer little valuable return (since they were ignored) though the blooms appeared in good condition. From late September, for example, I was unable to detect nectar in fresh-looking *Trifolium pratense*. By early October, native forage in the study area was reduced to small numbers of blooms persisting unusually late, and a late flush of *Lonicera periclymenum* which was ignored by *Bombus*. The only native species regularly used was an isolated late clump of *Cirsium vulgare* attracting dwindling numbers of increasingly indolent male *B. pascuorum*, virtually all activity being confined (as at the beginning of the season) to the garden.

This picture of the availability of native forage in northern Scotland is matched by the pattern of native species actually visited by bees at Strathpeffer (Figure 2). The same figure shows how exotic species as a group (often planted specifically to provide early and late colour) are less synchronised and compensate for the deficit of native forage at each end of the season. In summary, native plants were very limited both in diversity and abundance for most of the summer, except for July and August. Even the selection available in spring and autumn was not suitable or preferred forage for some species. Appendix 2 lists those native species which were common and available to bees at Strathpeffer, but which were never recorded as forage. Some of these have been recorded as significant food sources by other workers, emphasising that the forage used is a choice influenced by the range of plants available.

Bee Seasons

General data on the seasons of the five bees are shown in Table 1. I have little comparable data for other years at Strathpeffer, but there is significant variation in emergence dates, especially in the two earlier-emerging species, probably determined to some extent by the weather. First queens (in four years for *lucorum* and three for the rest) were recorded as follows: *lucorum* 11th March - 9th April; *pratorum* 23rd March - 9th April; *hortorum* 13th - 19th April; *pascuorum* 20th - 26th April; and *bohemicus* 15th - 25th April. There was no consistency between species: an early year for one might be a late year for another. The annual variation in emergence dates does change the nature of the forage available to the early bees, especially as the emergence of suitable forage does not necessarily vary in parallel with that of the bees. In some previous years, and in 1998, I have known *B. lucorum* (and only this species among bumble-bees) to feed in spring at *Salix*

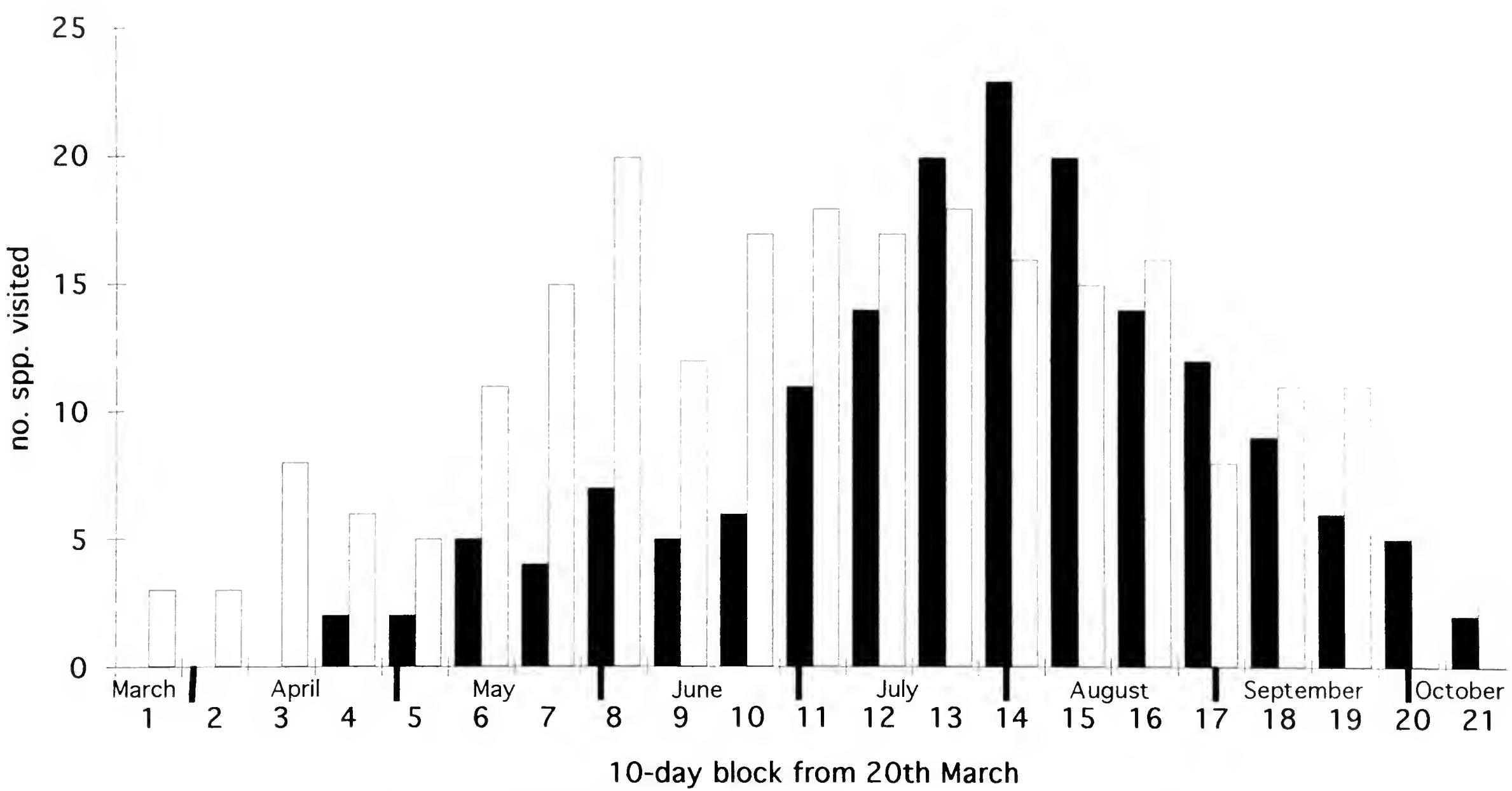


Figure 2. Numbers of Native (black bars) and Exotic (white bars) Forage Species used by *Bombus* and *Psithyrus* at Strathpeffer during 1997.

spp., but in 1997 the catkins were virtually over before the queens emerged and no foraging at *Salix* was recorded.

Comparison with data from Prys-Jones (1982) for populations in Cambridgeshire 700 km to the south (Table 1) shows a mixed picture. The overall season of *pratorum* was shorter at Strathpeffer by 12-42 days and that of *pascuorum* up to 17 days shorter, but the season of *hortorum* was 5-9 days longer and that of *lucorum* 2-18 days longer. The greatest difference was the much longer interval to the appearance of the first male of *hortorum* in the north (91 days compared with 53-59 days). The only possible trend in the data was for a shorter worker season at Strathpeffer in three of the four species common to both studies, at 7-27 days less in *pascuorum,* 11-21 days in *hortorum*, and 17-33 days in *pratorum*. In *lucorum*, however, the season for workers was 31-61 days longer in Strathpeffer. The results of less intensive observations in 1998 (which was notably cool and wet) suggested that the season for workers was even shorter than in 1997: 120 days for *lucorum* (taking it just inside the Cambridge range), 86 for *pratorum*, 70 for *hortorum* and 120 days for *pascuorum.* It is not possible to draw far-reaching conclusions from four years' data (two in Scotland and two in Cambridge), but they do suggest that short summer seasons are a significant factor in the ecology of northern populations, limiting especially the active season for workers, and (less certainly) that *hortorum* colonies may develop more slowly there.

The patterns of activity of individual bee species is shown in Figure 3. These follow the expected general pattern for the castes/sexes. Although only *lucorum* and *pascuorum* were significantly active in September and October, and that activity involved relatively few individuals, there is no doubt that the activity was productive and that colonies were still viable. Queens were foraging for hibernation, fresh workers were present in small numbers, and fresh males were clearly being produced. Workers of both species were seen (as in previous years) carrying pollen in early October. I have rarely known bumble-bees to be active at Strathpeffer beyond 15th October, and then only a few *B. soroeensis*.

Observations on *hortorum* and *pascuorum* from Coigach in the west of Scotland suggest that the season there was considerably later than in Strathpeffer. I have no reliable emergence dates for bees in the west, but the following observations are significant. A queen *pascuorum* in Coigach was seen carrying pollen on 25th July, 22 days after they had stopped in Strathpeffer. On 20th September in Coigach fresh-looking worker *pascuorum* were collecting pollen following a gap of 16 days in Strathpeffer, and *hortorum* workers were foraging 25 days after the last worker was seen in the east. On the same date the bees in

Coigach were continuing near-peak activity, foraging mainly in gardens on exotic plants (notably *Fuchsia magellanica*), though in one meadow *Stachys palustris* and *Centaurea nigra* were used. By this date, bees at Strathpeffer had been in decline for several weeks. A similar picture emerged in 1998. These comparisons suggest that in Strathpeffer these species were at least three weeks, and probably more, ahead of the same species in the west. At Kinlochbervie, in broadly similar habitat to Coigach but 50 km farther north, there was no significant forage and no bee activity on 18th October, thus suggesting that activity in the west did not continue later into the autumn than in the east to compensate for the later start.

Pollen Gathering

The phenology of pollen gathering activity is shown for the four *Bombus* species in Figure 4. Slight differences between the species are not explicable from the present data. Uniquely, *B. lucorum* queens showed two early periods of pollen collection. In *B. pratorum*, collection of pollen by queens and by workers was almost exclusive in time, while the others overlapped considerably, possibly indicating tighter synchrony between *pratorum* colonies. Autumn queens of two species (*lucorum* and *pascuorum*) were recorded collecting pollen, a practice noted by Prys-Jones and Corbet (1987) as indicating the replacement after death or loss of status of the old queen, or (but not in these species) establishment of second broods. If either happened at Strathpeffer, the late date makes it unlikely that they would be successful.

Forage Species

In total, 116 species were recorded as forage during the study, 77 of which featured as core forage, and only three of which (*Borago officinalis, Lamium purpureum, Vicia faba*) were annuals. A summary of some characteristics of forage plants used by the bees is given in Table 2. Information on nectar secretion was obtained from Hutchinson (1955), Clapham, Tutin and Warburg (1962), Proctor and Yeo (1973) and from direct observation. Allocation of some blooms to the categories 'clustered' and 'drooping' was slightly subjective.

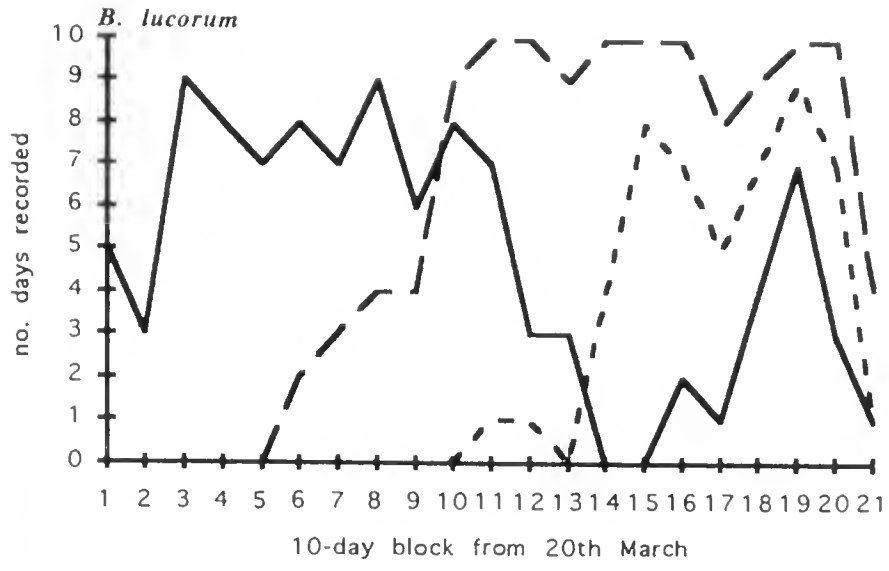
B. lucorum females used a higher proportion of pollen flowers than other species ($P = 0.01$ to 0.05 by chi-square and Fisher tests), and seven of the twelve flowers featuring only in its list are nectarless. They also appeared to visit a higher proportion of yellow flowers (5; 13%) than others, but four of these were also pollen flowers; hidden correlations of this sort may lead to faulty conclusions. (Casual observations and other data suggest that colour is less important than the provision of copious pollen. For example, *B. lucorum* was constant and numerous

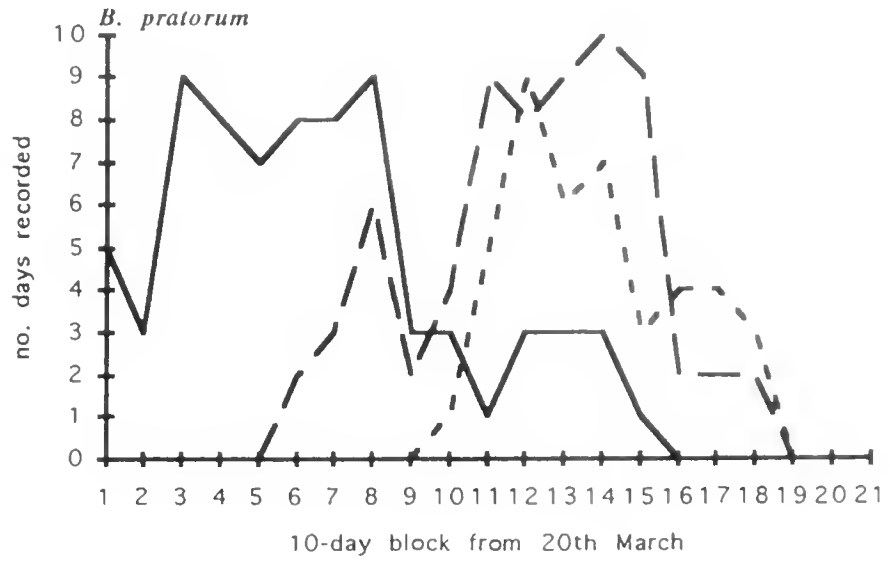
Figure 3

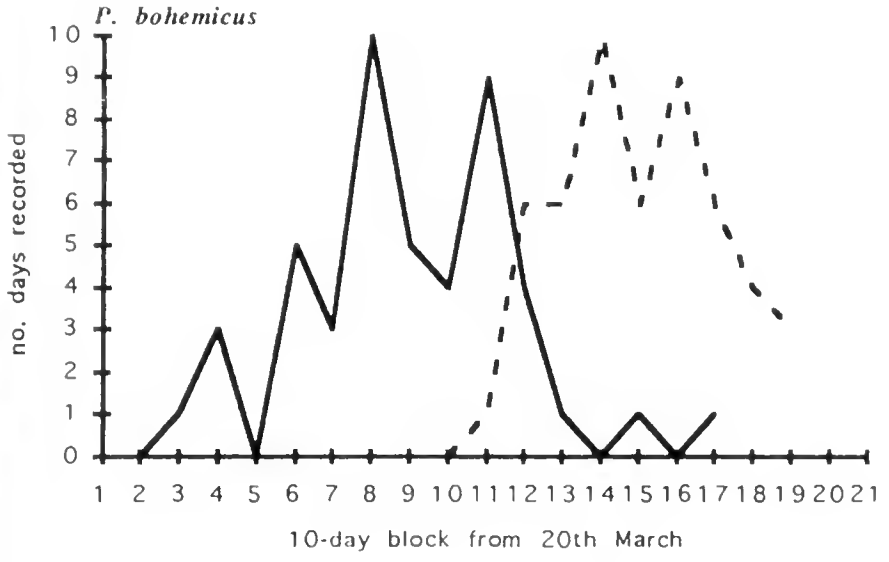
Seasonal Variation in Activity of the Five Bees at Strathpeffer in 1997

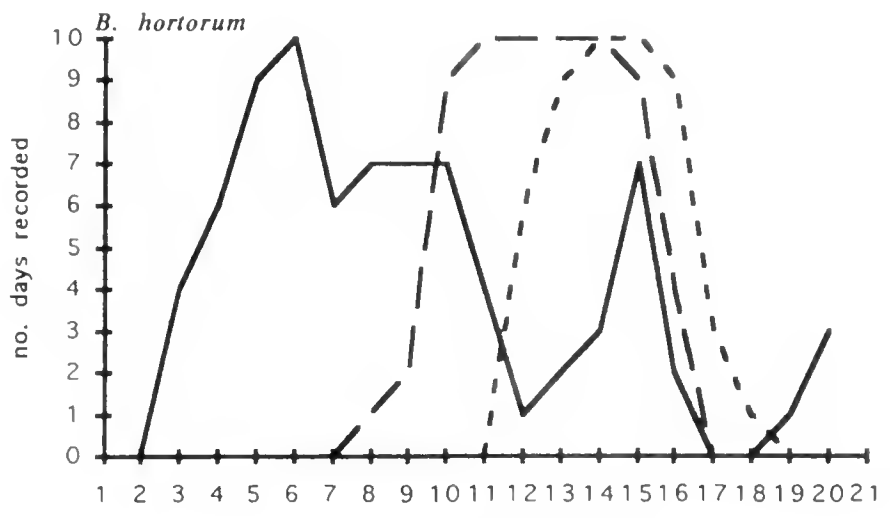
Solid lines = queens; long dashes = workers; short dashes = males.

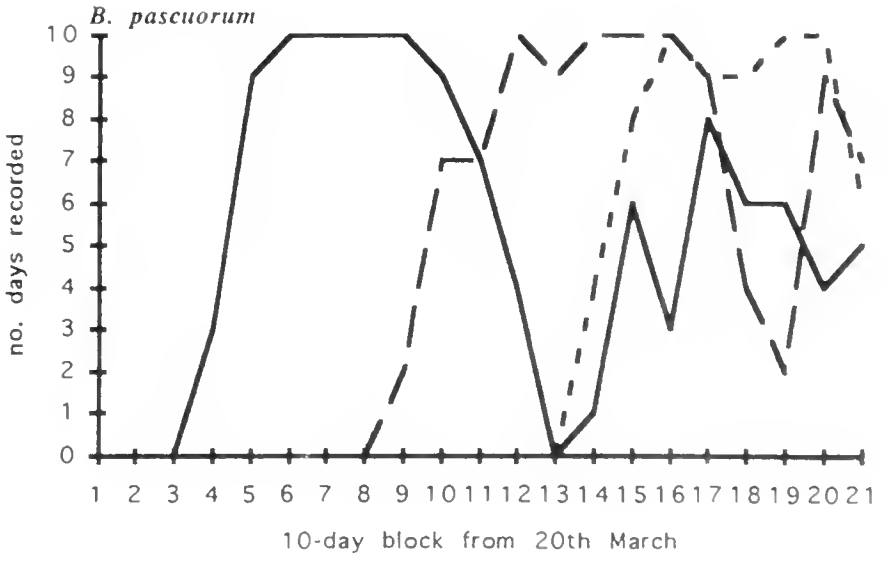
The approximate match of blocks to months is shown on the separate scale.











Approximate conversion of blocks to months:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
M	.	.	A	.	.	.	.	.	M	.	.	.	.	.	J	.	.	.	.	.	J	.	.	.	.	.	A	.	.	.	.	.	S	.	.	.	.	.	O	.	.

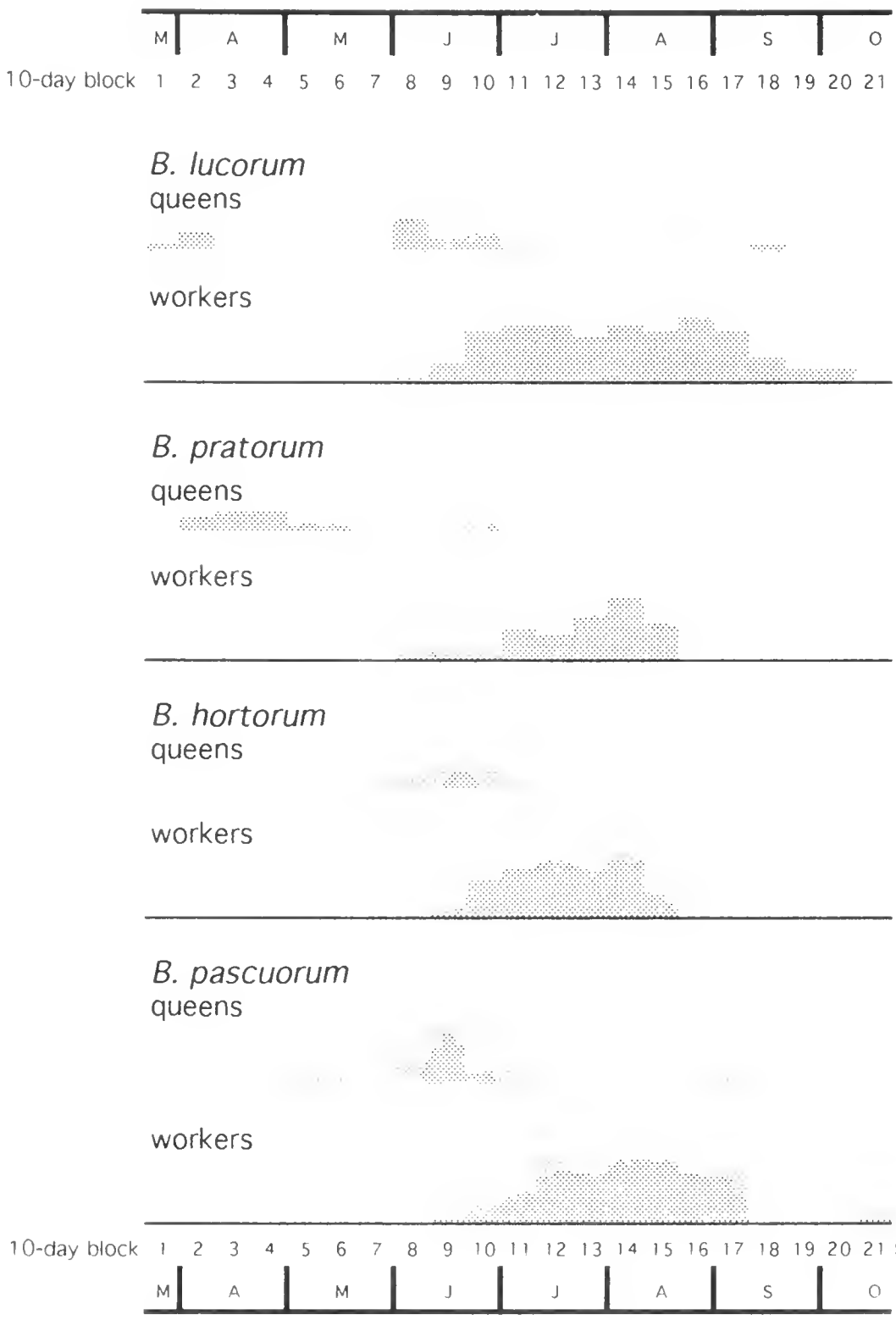


Figure 4

The Phenology of Pollen Collection by Four *Bombus* Species at Strathpeffer in 1997

The vertical axis gives the number of days on which pollen collection was observed, or bees were seen with pollen in the corbiculum.

Species:		*B. lucorum*	*B. pratorum*	*B. hortorum*	*B. pascuorum*	*P. bohemicus*
no. plant species:	total	72	39	62	60	34
	used by female	69	38	57	59	25
	used by male	18	9	24	14	15
	common	15(21)	8(21)	19(31)	13(22)	6(18)
	used by male only	3(4)	1(3)	5(8)	1(2)	9(26)
excluded:	(female)	31(43)	19(50)	29(51)	20(33)	4(16)
	(male)	5(28)	0(0)	5(21)	1(7)	2(13)
	core spp. (female)	*38*	*19*	*28*	*39*	*21*
	core spp. (male)	*13*	*9*	*19*	*13*	*13*
unique to bee*:	(female)	12(32)	2(11)	3(11)	7(18)	11(52)
	(male)	4(31)	2(22)	9(47)	2(15)	3(23)
native spp.	(female)	16(42)	9(47)	8(29)	18(46)	5(24)
	(male)	6(46)	6(67)	8(42)	8(62)	7(54)
nectarless flowers	(female)	9(24)	0(0)	1(4)	2(5)	0(0)
bilateral flowers	(female)	8(21)	6(32)	17(61)	19(49)	3(14)
	(male)	1(8)	2(22)	11(58)	3(23)	1(8)
spurred flowers	(female)	0(0)	0(0)	3(11)	2(5)	1(5)
	(male)	0(0)	0(0)	3(16)	0(0)	0(0)
clustered flowers	(female)	9(24)	3(16)	4(14)	12(31)	7(33)
	(male)	5(38)	3(33)	5(26)	5(38)	8(62)
drooping flowers	(female)	13(33)	9(47)	5(19)	5(13)	7(33)
	(male)	4(31)	3(33)	1(5)	3(23)	2(15)
woody plants	(female)	23(61)	12(63)	13(46)	12(31)	10(48)
	(male)	6(46)	4(44)	7(37)	4(31)	3(23)
females recorded at	<1m	248(52)	143(59)	282(78)	395(84)	61(84)
	1-2m	166(35)	89(36)	70(19)	76(16)	9(12)
	>2m	65(14)	12(5)	8(2)	2(0)	3(4)
males recorded at	<1m	52(65)	22(58)	102(63)	61(47)	35(51)
	1-2m	28(35)	16(42)	59(37)	69(53)	34(49)
	>2m	0(0)	0(0)	1(1)	0(0)	0(0)

Table 2

Summary of some Characteristics of the Forage Plants Used

Entries are numbers, with percentages in parentheses where appropriate. Core species are those forage species not excluded under the criteria given in the text. Clustered flowers include Asteraceae and others where many flowers can be probed without taking flight. All entries below 'core species' entry, except for foraging heights, are based on core species only. Some percentages may not total to 100 due to rounding errors. *The number of forage species found only in the core list of one bee species, sexes considered separately.

at *Aruncus dioicus*, an ivory-coloured pollen species virtually ignored by other *Bombus*, in a garden in Dingwall some 8.0 km east of Strathpeffer). The female *hortorum* ($P<0.01$) and *pascuorum* ($P<0.05$) lists showed a significantly greater proportion of zygomorphic (bilaterally symmetrical) flowers than *lucorum* and *P. bohemicus*. *B. pratorum* females were recorded at more drooping species than were female *hortorum* ($P=0.04$) and *pascuorum* ($P=0.008$). *B. lucorum* females used a higher proportion of woody plants than *hortorum*, and both *lucorum* and *pratorum* a higher proportion than *pascuorum* ($P<0.05$). Other apparent differences in the table are not statistically significant, possibly in some cases due to small samples.

B. lucorum females were the only bees to forage regularly in trees (at up to 8.0 m). Their foraging distribution was significantly higher than females of all other species ($P<0.001$ by chi-square), and female *pratorum* significantly higher than females of *hortorum*, *pascuorum* and *P. bohemicus* ($P<0.001$). Male *lucorum* and *hortorum* were recorded significantly lower than *pascuorum* males ($P<0.05$ and <0.01 respectively). The ecological significance of these differences is not clear, but as far as differences in foraging height below 2.0 m are concerned seemed to reflect the distribution of the preferred forage rather than any preferred height range. I detected no stratification on plants whose blooms extended from ground to 2.0 m, and windthrow of tall plants like *Chamerion angustifolium*, *Digitalis purpurea* and *Aconitum* spp. had no apparent effect on their attractiveness as forage, though my observations will not have been detailed enough to reveal differences on the scale demonstrated by Barrow (1983). Female *lucorum* (especially) and *pratorum* were apparently more inclined to fly high and encounter arboreal flowers (*cf.* Brian, 1957). Males had little opportunity to feed at high levels as no trees were in flower when they were active.

Specific details of the forage used by the bees is provided in Table 3. Queens and workers of *B. lucorum* were recorded feeding on honeydew produced by Psyllid bugs on the twigs of a single *Crataegus monogyna* on three occasions between 11th May and 4th June. These records are not included in the analyses. In 1998, *lucorum* queens were recorded at *Salix caprea* on six days between 28th March and 2nd April, (but not on an ornamental *Salix* covered in conspicuous male catkins during the same period). Only three plants were common to all core female lists (*Pulmonaria*, *Rubus fruticosus* and *R. idaeus*), and three to the male lists (*Chamerion angustifolium*, *Cirsium vulgare* and *R. fruticosus*). The species/sexes showed distinct differences in their relative use (as indicated by number of records) of different plants even where they were shared, and the differences persisted even when the influence of differing active seasons was reduced by considering only block 5-17 when females of all bee species were active (Table 3).

Table 3

(Pages 70 to 74)

Core Forage Plants used by the Five Species of Bee at Strathpeffer in 1997

with the number of records of each for the whole season, and in brackets the number for the period of overlap of females in blocks 5-17 inclusive.

The *Viola* hybrid was very similar to *V. tricolor* in appearance and was probably a reversion.

B. lucorum

(females)	
Borago officinalis	44(19)
Rubus fruticosus	31(31)
Chamerion angustifolium	25(21)
Rubus idaeus	24(24)
Sedum spectabile	23
Cytisus scoparius	20(20)
Lupinus x *regalis*	19(18)
Ribes sanguineum	18
Trifolium repens	18(18)
Acer pseudoplatanus	17(17)
Hypericum pseudohenryi	15(11)
Symphoricarpos albus	15(11)
Erica tetralix	14(12)
Symphoricarpos x *chenaultii*	14
Sedum spurium	13(12)
Rosa canina agg.	12(12)
Cirsium arvense	11(9)
Filipendula ulmaria	11(11)
Prunus avium	11(7)
Rhododendron ponticum	10(10)
Pulmonaria sp.	9
Rhododendron sp.	8(8)
Aesculus hippocastanum	7(7)
Prunus serrulata	7
Cirsium vulgare	6(2)
Meconopsis cambrica	6(6)
Aconitum japonicum	5
Calluna vulgaris	5(3)
Erica carnea	5
Helianthemum sp.	5(5)
Potentilla fruticosa	5(4)
Rosa rugosa	4(4)
Tilia x *vulgaris*	4(4)
Polygonum bistorta	3(1)
Ribes nigrum	3
Ulex europaeus	3(3)
Campanula latifolia	2(2)
Levisticum officinale	2(2)

(males)	
Chamerion angustifolium	19
Sedum spectabile	14
Borago officinalis	12
Calluna vulgaris	9
Erica tetralix	8
Cirsium vulgare	5
Polygonum bistorta	3
Rubus fruticosus	3
Aconitum japonicum	1
Cirsium arvense	1
Potentilla fruticosa	1
Symphoricarpos x *chenaultii*	1
Symphoricarpos albus	1

B. pratorum

(females)	
Pulmonaria sp.	47(26)
Borago officinalis	25(25)
Rubus fruticosus	22(22)
Ribes sanguineum	19(5)
Symphoricarpos albus	19(17)
Chamerion angustifolium	17(17)
Rubus idaeus	16(16)
Rhododendron sp.	10(10)
Ribes nigrum	6(2)
Lamiastrum galeobdolon	5(5)
Acer pseudoplatanus	4(4)
Cirsium vulgare	4(4)
Erica carnea	4(1)
Aesculus hippocastanum	3(3)
Cirsium arvense	3(3)
Prunus avium	3(2)
Trifolium repens	3(3)
Hebe sp.	1(1)
Lavandula x *intermedia*	1(1)

(males)	
Rubus fruticosus	14
Chamerion angustifolium	11
Rubus idaeus	4
Borago officinalis	3
Lavandula x *intermedia*	3
Symphoricarpos albus	3
Cirsium palustre	1
Cirsium vulgare	1
Trifolium repens	1

B. hortorum

(females)		(males)	
Nepeta x *faassenii*	40(40)	*Aconitum* x *cammarum*	24
Salvia officinalis	40(40)	*Rubus fruticosus*	23
Pulmonaria sp.	35(26)	*Cirsium vulgare*	22
Digitalis purpurea	31(31)	*Nepeta* x *faassenii*	20
Cirsium vulgare	23(23)	*Digitalis purpurea*	15
Rhododendron ponticum	20(20)	*Buddleja davidii*	10
Rubus fruticosus	18(18)	*Lavandula* x *intermedia*	8
Lonicera periclymenum	17(17)	*Calystegia silvatica*	7
Trifolium pratense	14(14)	*Salvia officinalis*	6
Lavandula x *intermedia*	12(12)	*Lonicera periclymenum*	5
Vicia sepium	11(11)	*Erica tetralix*	4
Ajuga purpurea	8(8)	*Pelargonium zonale*	4
Lupinus x *regalis*	8(8)	*Sedum spurium*	4
Vicia faba	8(8)	*Centaurea montana*	3
Buddleja davidii	7(7)	*Chamerion angustifolium*	3
Stachys byzantina	6(6)	*Trifolium pratense*	3
Viola x	5(5)	*Viola* x	2
Aconitum x *cammarum*	4(4)	*Vicia faba*	1
Pelargonium zonale	4(4)	*Vicia sepium*	1
Rhododendron sp.	4(4)		
Ribes sanguineum	3		
Rubus idaeus	3(3)		
Sedum spurium	3(3)		
Primula x *polyantha*	2(1)		
Aconitum japonicum	1		
Calystegia silvatica	1(1)		
Erica tetralix	1(1)		
Pieris forrestii	1		

B. pascuorum

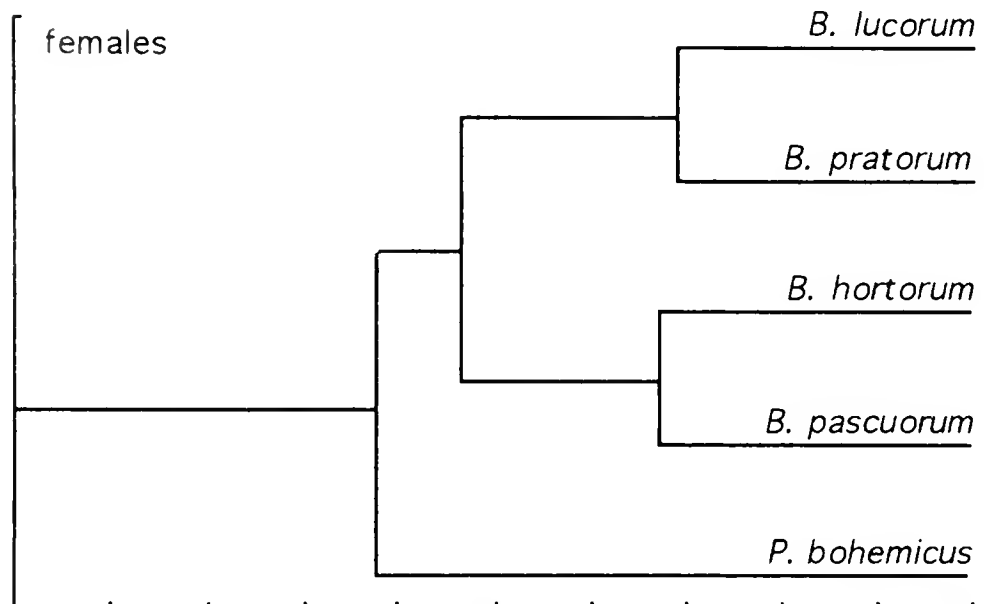
(females)	
Vicia sepium	51(51)
Pulmonaria sp.	38(35)
Vicia cracca	29(29)
Borago officinalis	28(26)
Chamerion angustifolium	27(24)
Lathyrus pratensis	27(26)
Ajuga purpurea	24(24)
Aconitum japonicum	23
Rubus idaeus	23(23)
Trifolium pratense	20(20)
Cirsium vulgare	19(19)
Digitalis purpurea	16(16)
Rubus fruticosus	15(15)
Trifolium repens	15(15)
Nepeta x *faassenii*	14(14)
Stachys byzantina	13(13)
Salvia officinalis	11(11)
Centaurea montana	9(9)
Cirsium palustre	9(9)
Sedum spurium	9(9)
Erica tetralix	7(7)
Lavandula x *intermedia*	7(7)
Arctium minus	6(6)
Helianthemum sp.	6(4)
Pelargonium zonale	6(4)
Stachys sylvatica	6(6)
Erysimum sp.	5(5)
Lupinus x *regalis*	4(4)
Ajuga reptans	3(3)
Campanula latifolia	3(3)
Cirsium arvense	3(3)
Lamium purpureum	3(3)
Rhododendron ponticum	3(3)
Buddleja davidii	2(2)
Calluna vulgaris	2(2)
Symphoricarpos albus	2(2)
Calystegia silvatica	1
Sedum spectabile	1
Rhododendron sp.	1(1)

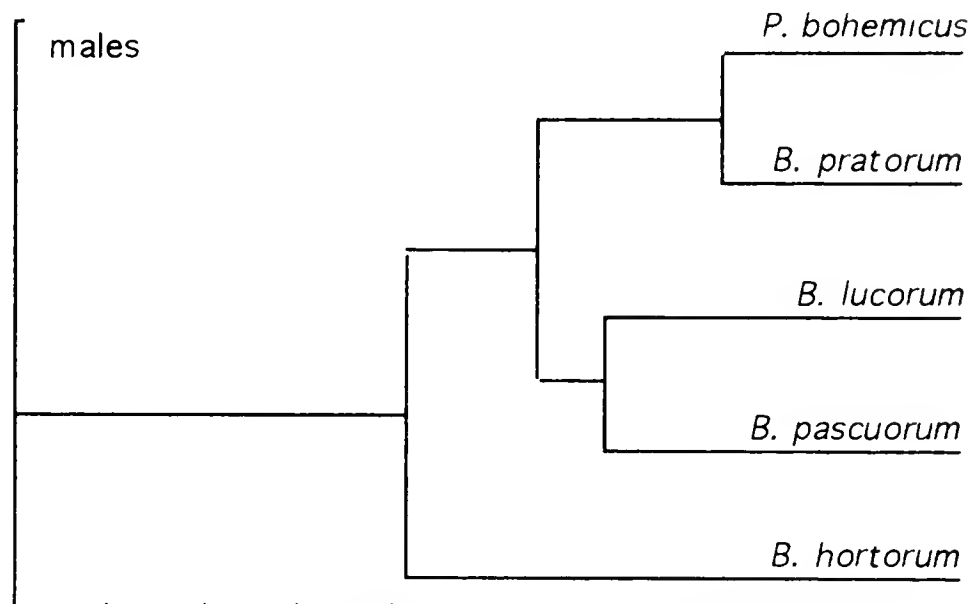
(males)	
Cirsium vulgare	51
Chamerion angustifolium	26
Borago officinalis	9
Nepeta x *faassenii*	9
Cirsium palustre	7
Symphoricarpos albus	7
Rubus fruticosus	5
Calystegia silvatica	4
Vicia cracca	4
Erica tetralix	3
Arctium minus	2
Calluna vulgaris	2
Aconitum japonicum	1

P. bohemicus

(females)	
Rubus idaeus	15(15)
Centaurea montana	10(10)
Polygonum bistorta	10(10)
Ajuga purpurea	4(4)
Thymus polytrichus	4(4)
Cotoneaster sp.	2(2)
Erica carnea	2(2)
Erica cinerea	2(2)
Fragaria ananassa	2(2)
Geum borisii	2(2)
Malus domestica	2(2)
Pieris forrestii	2
Pulmonaria sp.	2(2)
Taraxacum vulgaris agg.	2(2)
Viola x	2(2)
Acer pseudoplatanus	1(1)
Armeria maritima	1(1)
Astrantia major	1(1)
Borago officinalis	1(1)
Rubus fruticosus	1(1)
Spiraea x *arguta*	1(1)

(males)	
Rubus fruticosus	24
Chamerion angustifolium	15
Cirsium vulgare	7
Cirsium palustre	6
Astrantia major	5
Calluna vulgaris	3
Lavandula x *intermedia*	3
Erica cinerea	2
Sedum spurium	2
Borago officinalis	1
Centaurea montana	1
Sedum spectabile	1
Taraxacum vulgaris agg.	1





females

B. pratorum	0.692	------		
B. hortorum	0.379	0.444	------	
B. pascuorum	0.562	0.552	0.670	------
P. bohemicus	0.385	0.317	0.235	0.360
	B. lucorum	*pratorum*	*hortorum*	*pascuorum*

males

B. pratorum	0.523	------		
B. hortorum	0.278	0.412	------	
B. pascuorum	0.624	0.576	0.481	------
P. bohemicus	0.532	0.748	0.495	0.591
	B. lucorum	*pratorum*	*hortorum*	*pascuorum*

Figure 5. Dendrograms showing the Similarity in Diet of the Five Species of Bee at Strathpeffer in 1997, based on Horn's (1966) index of overlap. The indices are given in the tables.

Dietary overlap and breadth

Overlap indices for all pairs of species separated by sex, and the dendrograms derived from them by the method given in Bridge (1993), are given in Figure 5. The females separated as one might have expected, the two long-tongued species grouped together and the two short-tongued *Bombus* together, with *Psithyrus* on its own. When the effects of the different active seasons were removed by considering only the data for blocks 5-17 inclusive, when females of all the species were active, the picture changed in only very minor respects. Males separated quite differently: *B. pratorum* with *P. bohemicus, B. lucorum* with *B. pascuorum,* and *B. hortorum* on its own. The same groupings, but with lower similarity values, were obtained with the less precise Jaccard's coefficient (Bridge, 1993) based on shared species only, irrespective of their contribution. In case these data emphasise too much the similarities between the diets of female *Bombus*, it should be noted that when the data for blocks 5-17 were analysed using the Spearman rank correlation, r_s for the pairs *lucorum* v. *pratorum* and *hortorum* v. *pascuorum* was only 0.13 and 0.15 respectively, reflecting great differences in relative use of forage species common to both lists.

Table 4 shows that all bees relied for all or most of the year on very few forage species, with typically 1-4 plant species providing 75% of records in any block. All species had a low breadth at the beginning and end of the season. *B. pratorum* showed little variation from a restricted diet throughout the year, while the other *Bombus,* and especially *pascuorum*, enjoyed a much more diverse diet in late summer coinciding broadly with the main worker season.

Phenology of Forage Use

The phenology of the use of native and exotic forage is shown in Figures 6 to 10. It is clear that all species of bee were wholly dependent on exotic forage for varying periods at the beginning of the season. *B. lucorum* was not seen to feed at any native core species until 35 days after emergence (17% of its total season); *pratorum* 34 days (20%); *hortorum* 50 days (29%); *pascuorum* 14 days (8%) and *P. bohemicus* 12 days (8%). At the end of the season, during the last 30 days exotic species dominated the forage of male and female *lucorum,* and female *pascuorum.* Figure 11 shows the contribution of native species through the season as percentage of all records. In general, males made more use of native forage than females, in part as a result of their absence early in the year, but *B. hortorum* had a particularly low contribution from native forage in both sexes.

10-day block.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
B. lucorum																						
females:	no. spp. used	2	2	5	4	3	3	4	7	5	9	14	10	9	10	10	7	6	10	8	8	2
	no. native spp.	0	0	0	1	2	2	3	5	2	4	6	5	7	8	7	4	2	3	3	2	1
	N 75%	1	2	3	3	2	2	2	4	3	4	7	4	6	5	6	4	3	5	4	4	1
	breadth of diet	1.38	2.00	3.86	3.67	2.17	2.18	2.52	4.43	3.56	6.32	9.85	5.63	6.02	6 76	8.33	4.10	4 48	6 63	4 48	4 64	1 47
males:	*no. spp. used*											*1*			*2*	*4*	*3*	*3*	*6*	*9*	*4*	*1*
	no. native spp.											*0*			*2*	*4*	*3*	*3*	*3*	*3*	*1*	*0*
	N 75%											*1*			*1*	*2*	*2*	*2*	*3*	*4*	*2*	*1*
	breadth of diet											*1.00*			*1.60*	*2.94*	*2 46*	*1 81*	*3 76*	*4 40*	*2 38*	*1 00*
B. pratorum																						
females:	no. spp. used	3	2	3	4	5	5	4	3	2	2	3	3	7	5	4	1	2	1			
	no. native spp.	0	0	0	1	1	1	1	0	1	1	1	1	5	3	3	1	1	0			
	N 75%	3	2	2	2	2	3	2	2	2	2	2	2	4	3	3	1	2	1			
	breadth of diet	3.00	1.92	2.71	2.41	2.76	3.00	3.04	2.17	1.80	2.16	2.32	2.67	4 76	3.70	3 00	1 00	1 80	1 00			
males:	*no. spp. used*											*2*	*4*	*3*	*3*	*2*	*2*	*1*	*2*			
	no. native spp.											*1*	*3*	*1*	*3*	*2*	*2*	*1*	*1*			
	N 75%											*2*	*2*	*2*	*2*	*2*	*2*	*1*	*2*			
	breadth of diet											*1.92*	*2.29*	*2.58*	*2.00*	*1.80*	*2 00*	*1 00*	*2 00*			
B. hortorum																						
females:	no. spp. used			4	1	1	3	2	7	4	8	8	7	11	13	8	5				1	
	no. native spp.			0	0	0	0	0	1	1	3	3	4	5	5	3	3				0	
	N 75%			2	1	1	1	2	4	3	4	4	5	6	5	5	3				1	
	breadth of diet			3.20	1.00	1.00	1.41	1.80	5.12	3.33	5.94	6.02	6.01	8.70	8.81	7.56	4 17				1 00	
males:	*no. spp. used*												*5*	*6*	*15*	*13*	*8*	*2*	*1*			
	no. native spp.												*3*	*3*	*8*	*6*	*5*	*1*	*0*			
	N 75%												*3*	*4*	*7*	*7*	*5*	*1*	*1*			
	breadth of diet												*3.31*	*4.96*	*9.66*	*8 68*	*5 74*	*1 60*	*1 00*			
B. pascuorum																						
females:	no. spp. used		1	2	3	3	8	8	7	8	12	14	17	22	16	11	4	2	2	3		
	no. native spp.		0	0	1	1	2	4	3	3	6	10	12	12	10	7	2	0	0	1		
	N 75%		1	1	2	2	4	4	4	4	5	8	9	12	7	5	3	1	1	1		
	breadth of diet		1.00	1.22	1.78	2.16	5.50	4.53	4.90	4.10	6.03	10.96	12.31	16.64	9 00	7.26	3 60	1 32	1 22	1 59		
males:	*no. spp. used*												*3*	*5*	*8*	*8*	*8*	*5*	*5*	*3*		
	no. native spp.												*3*	*5*	*7*	*5*	*6*	*2*	*2*	*2*		
	N 75%												*3*	*3*	*5*	*4*	*4*	*2*	*2*	*2*		
	breadth of diet												*3.00*	*4.26*	*5 88*	*4 89*	*4.70*	*2 10*	*2 10*	*1 98*		
P. bohemicus																						
females:	no. spp. used	1	2		6	6	7	3	4	5	3	1				1						
	no. native spp.	0	1		2	0	1	1	1	3	2	1				0						
	N 75%	1	2		4	4	4	2	3	3	2	1				1						
	breadth of diet	1.00	2.00		5.33	4.76	6.06	2.67	2.58	4.84	2.27	1.00				1 00						
males:	*no. spp. used*									*1*	*4*	*3*	*5*	*5*	*6*	*3*	*2*	*3*				
	no. native spp.									*0*	*3*	*3*	*4*	*3*	*4*	*2*	*2*	*2*				
	N 75%									*1*	*2*	*2*	*2*	*4*	*4*	*2*	*2*	*3*				
	breadth of diet									*1.00*	*2.81*	*2.38*	*2.28*	*3.77*	*5 16*	*2.13*	*2.00*	*3 00*				

Table 4. Numbers of Forage Species used by the Five Bees and Measures of Dietary Breadth

N 75% gives the minimum number of forage species contributing 75% of records for each 10-day block. Where native species comprise more than 50% of all species used, the entries are underlined. Only core forage species are included.

Figure 6

The Phenology of Forage Use by *Bombus lucorum* at Strathpeffer, 1997

Native species are shown in black; exotic species in grey.

Numbers at the top give the 10-day blocks.

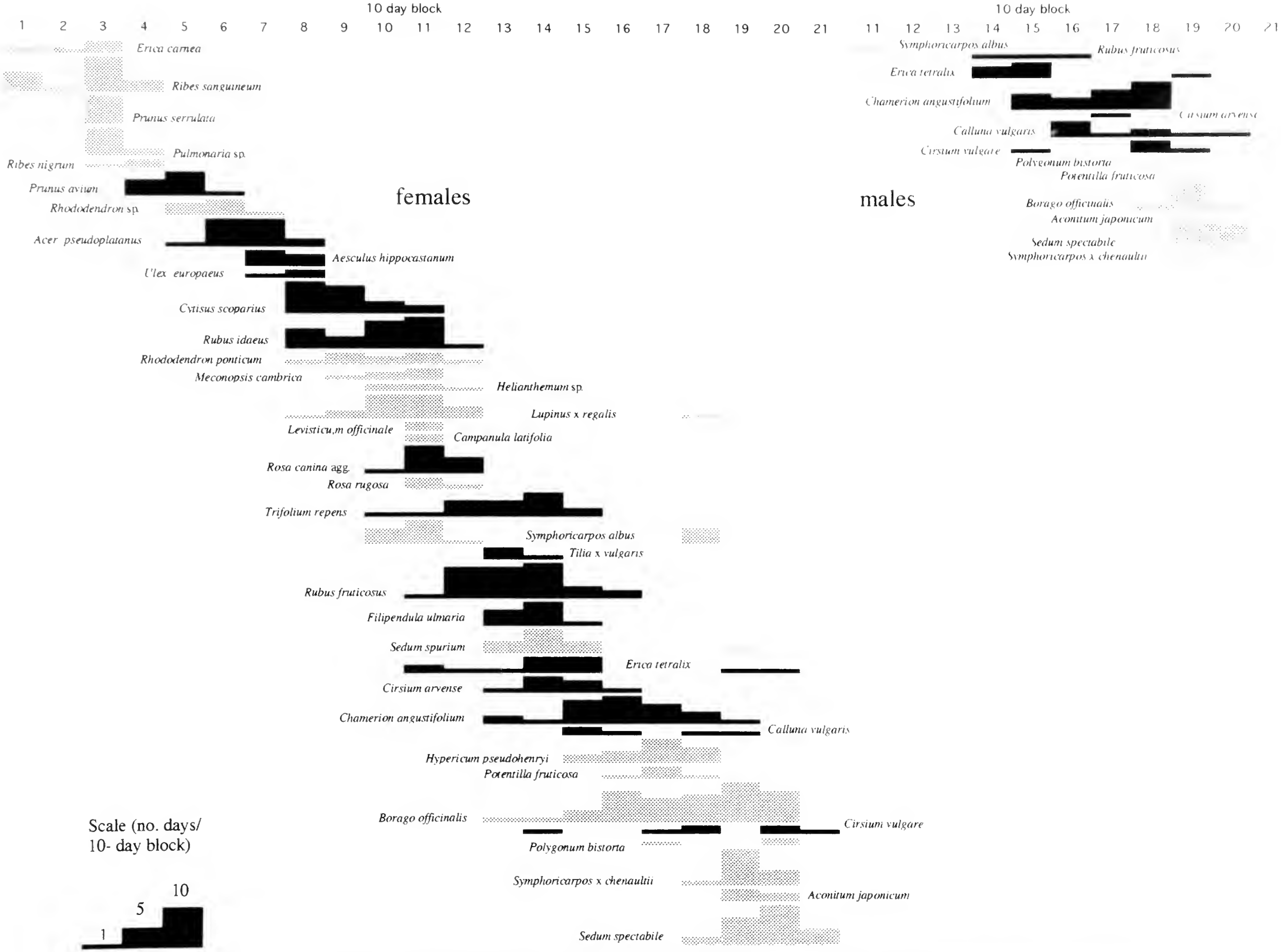

10 day block
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Erica carnea
Ribes sanguineum
Prunus serrulata
Pulmonaria sp.
Ribes nigrum
Prunus avium
Rhododendron sp.
Acer pseudoplatanus
Aesculus hippocastanum
Ulex europaeus
Cytisus scoparius
Rubus idaeus
Rhododendron ponticum
Meconopsis cambrica
Helianthemum sp.
Lupinus x regalis
Levisticum officinale
Campanula latifolia
Rosa canina agg.
Rosa rugosa
Trifolium repens
Symphoricarpos albus
Tilia x vulgaris
Rubus fruticosus
Filipendula ulmaria
Sedum spurium
Erica tetralix
Cirsium arvense
Chamerion angustifolium
Calluna vulgaris
Hypericum pseudohenryi
Potentilla fruticosa
Borago officinalis
Cirsium vulgare
Polygonum bistorta
Symphoricarpos x chenaultii
Aconitum japonicum
Sedum spectabile
females
10 day block
11 12 13 14 15 16 17 18 19 20 21
Symphoricarpos albus
Rubus fruticosus
Erica tetralix
Chamerion angustifolium
Cirsium arvense
Calluna vulgaris
Cirsium vulgare
Polygonum bistorta
Potentilla fruticosa
Borago officinalis
Aconitum japonicum
Sedum spectabile
Symphoricarpos x chenaultii
males
Scale (no. days/
10- day block)
1
5
10

Figure 7

The Phenology of Forage Use by *Bombus pratorum* at Strathpeffer, 1997

Native species are shown in black; exotic species in grey.

Numbers at the top give the 10-day blocks.

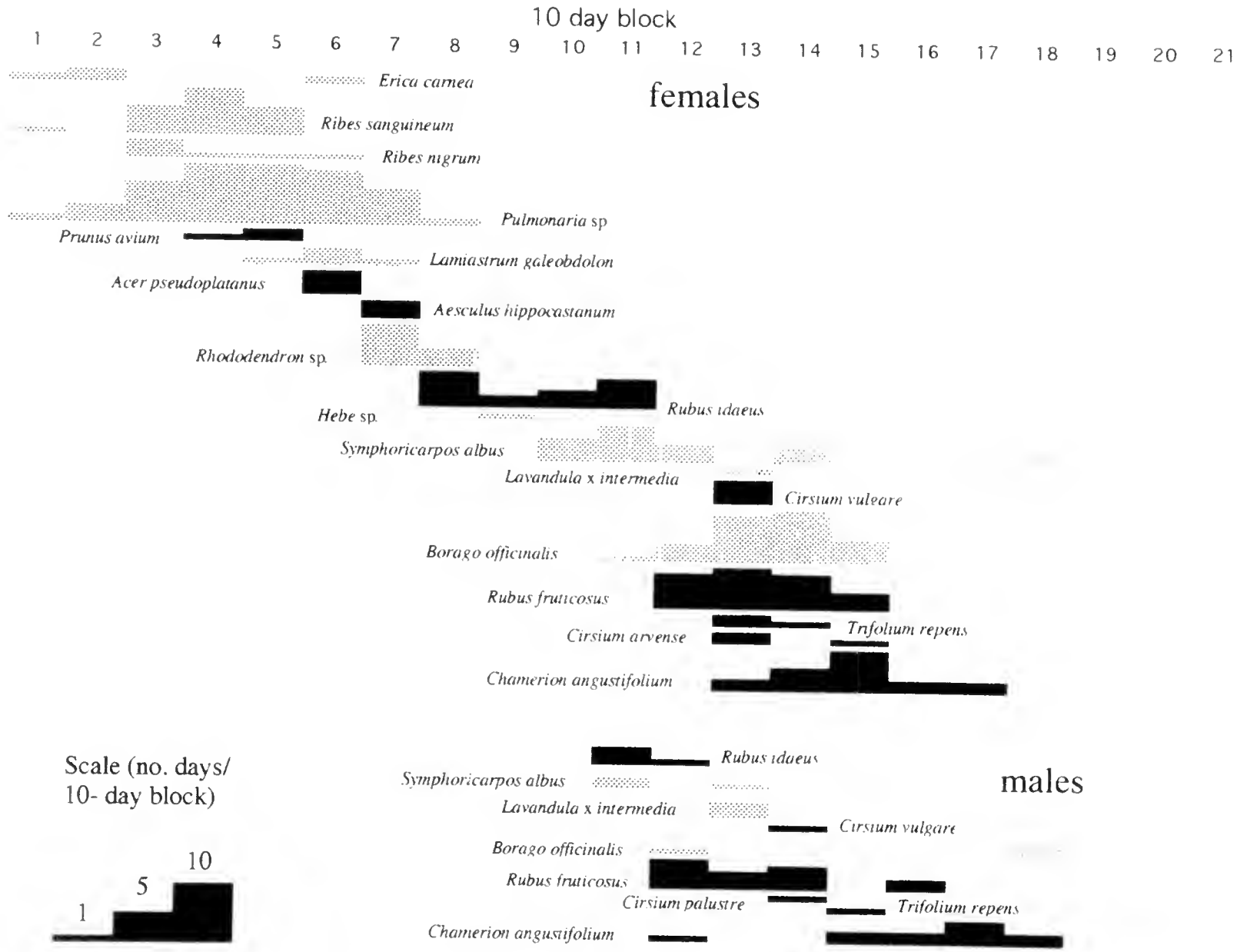
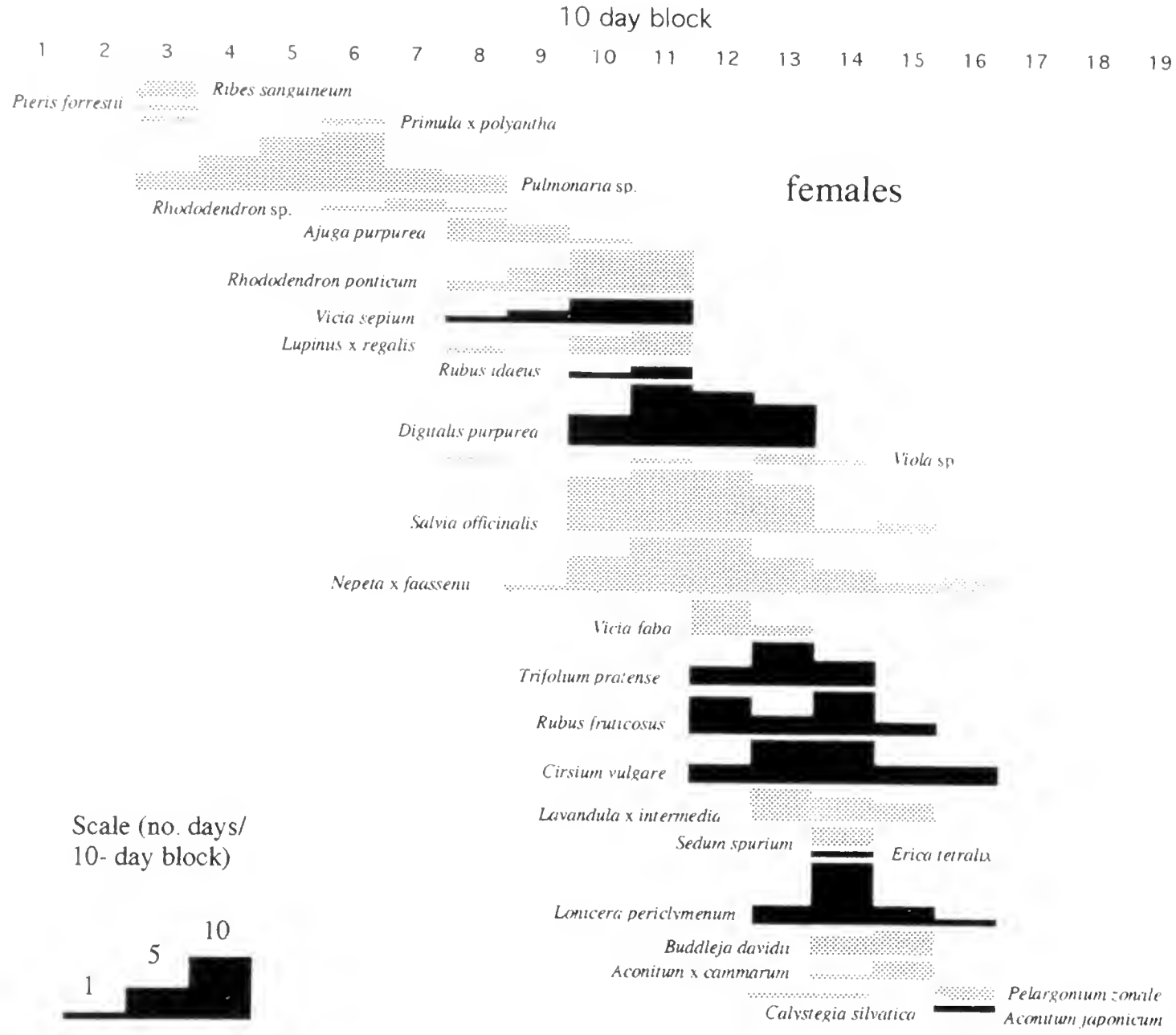

10 day block
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
females
Erica carnea
Ribes sanguineum
Ribes nigrum
Pulmonaria sp
Prunus avium
Lamiastrum galeobdolon
Acer pseudoplatanus
Aesculus hippocastanum
Rhododendron sp.
Hebe sp.
Rubus idaeus
Symphoricarpos albus
Lavandula x intermedia
Cirsium vulgare
Borago officinalis
Rubus fruticosus
Cirsium arvense
Trifolium repens
Chamerion angustifolium
Scale (no. days/
10- day block)
1
5
10
Rubus idaeus
Symphoricarpos albus
Lavandula x intermedia
Cirsium vulgare
Borago officinalis
Rubus fruticosus
Cirsium palustre
Trifolium repens
Chamerion angustifolium
males

Figure 8

The Phenology of Forage Use by *Bombus hortorum* at Strathpeffer, 1997

Native species are shown in black; exotic species in grey.

Numbers at the top give the 10-day blocks.


10 day block
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
females
Pieris forrestii
Ribes sanguineum
Primula x polyantha
Pulmonaria sp.
Rhododendron sp.
Ajuga purpurea
Rhododendron ponticum
Vicia sepium
Lupinus x regalis
Rubus idaeus
Digitalis purpurea
Viola sp
Salvia officinalis
Nepeta x faassenii
Vicia faba
Trifolium pratense
Rubus fruticosus
Cirsium vulgare
Lavandula x intermedia
Sedum spurium
Erica tetralix
Lonicera periclymenum
Buddleja davidii
Aconitum x cammarum
Calystegia silvatica
Pelargonium zonale
Aconitum japonicum

10 day block
12 13 14 15 16 17 18
males
Vicia faba
Vicia sepium
Salvia officinalis
Digitalis purpurea
Nepeta x faassenii
Rubus fruticosus
Trifolium pratense
Lavandula x intermedia
Sedum spurium
Lonicera periclymenum
Chamerion angustifolium
Centaurea montana
Erica tetralix
Viola sp
Cirsium vulgare
Buddleja davidii
Aconitum x cammarum
Calystegia silvatica
Pelargonium zonale

Scale (no. days/
10- day block)
1
5
10

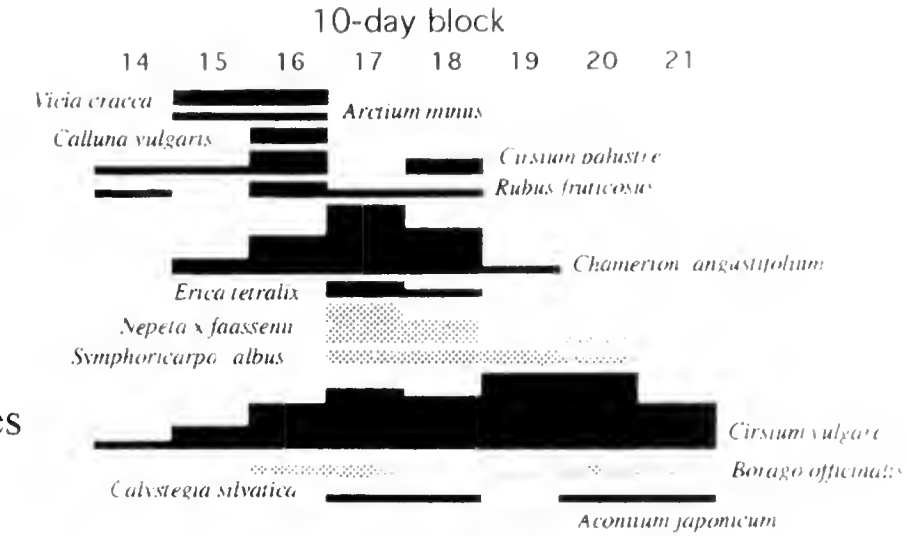
Figure 9

The Phenology of Forage Use by *Bombus pascuorum* at Strathpeffer, 1997

Native species are shown in black; exotic species in grey.

Numbers at the top give the 10-day blocks.

10-day block
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Rhododendron sp
Lamium purpureum
Pulmonaria sp.
Ajuga purpurea
Rhododendron ponticum
Lupinus x regalis
Ajuga reptans
Erysimum sp.
Rubus idaeus
females
Vicia sepium
Salvia officinalis
Helianthemum sp.
Campanula latifolia
Digitalis purpurea
Symphoricarpos albus
Rubus fruticosus
Centaurea montana
Trifolium repens
Lavandula x intermedia
Cirsium vulgare
Trifolium pratense
Arctium minus
Cirsium palustre
Nepeta x faassenii
Vicia cracca
Erica tetralix
Sedum spurium
Buddleja davidii
Cirsium arvense
Lathyrus pratensis
Stachys byzantina
Borago officinalis
Stachys sylvatica
Chamerion angustifolium
Pelargonium zonale
Calluna vulgaris
Sedum spectabile
Aconitum japonicum
Calystegia silvatica


10-day block
14 15 16 17 18 19 20 21
males
Vicia cracca
Arctium minus
Calluna vulgaris
Cirsium palustre
Rubus fruticosus
Chamerion angustifolium
Erica tetralix
Nepeta x faassenii
Symphoricarpos albus
Cirsium vulgare
Borago officinalis
Calystegia silvatica
Aconitum japonicum

Scale (no. days/
10- day block)
1
5
10

Figure 10

The Phenology of Forage Use by *Psithyrus bohemicus* at Strathpeffer, 1997

Native species are shown in black; exotic species in grey.

Numbers at the top give the 10-day blocks.

10-day block
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
females
Pieris forrestii
Taraxacum vulgaris agg.
Erica carnea
Pulmonaria sp.
Acer pseudoplatanus
Malus domestica
Geum borisii
Fragaria x ananassa
Polygonum bistorta
Cotoneaster sp
Ajuga purpurea
Viola x
Centaurea montana
Rubus idaeus
Armeria sp.
Astrantia major
Spiraea x arguta
Thymus polytrichus
Erica cinerea
Rubus fruticosus
Borago officinalis
males
Astrantia major
Erica cinerea
Cirsium palustre
Rubus fruticosus
Chamerion angustifolium
Sedum spurium
Lavandula x intermedia
Calluna vulgaris
Centaurea montana
Borago officinalis
Cirsium vulgare
Sedum spectabile
Taraxacum vulgaris agg
Scale (no. days/
10- day block)
1
5
10

Interspecific Competition?

In this study there was no evidence, such as exclusive foraging dates on the same plants, to suggest that forage choice was influenced by direct competition with other bumble-bees. Uniquely for well-utilised species, however, overall foraging activity on *Symphoricarpos albus* was bimodal (Figure 12). *B. lucorum* and *B. pratorum* moved on to it very soon after the first flowers opened in June (block 10). By early July (block 12), despite the fact that the flowers were still apparently productive, use dropped and this low level of use continued until mid-August (block 16), when these two bees plus *pascuorum* males began to use it again. Between mid-July and mid-August (blocks 13-15) *Symphoricarpos* was heavily used by hoverflies Syrphidae (especially *Volucella pellucens* and *Eristalis* spp.) and by social wasps Vespidae (especially *Dolichovespula sylvestris*). The disappearance of these at the beginning of September was followed by increased use by bumble-bees. The evidence is anecdotal, but deserves mention and further investigation.

Bumble-bees also occasionally stopped using certain species long before they seemed to be unproductive as forage. For example, *B. lucorum* moved on to *Tilia* x *vulgaris* soon after the flowers opened, but their interest lasted only nine days. For the next two weeks the flowers were heavily used by honey bees *Apis mellifera* and various Diptera, while I never recorded *Bombus*.

DISCUSSION

Bee Seasons in the Highlands

The five species of bee studied here show in their general ecology strong similarities to what is known from other parts of Britain, although this study area was much farther north than earlier British studies. There was little consistent difference in timing of the periods of activity, though in some years and for some species emergence was later and activity finished earlier than in southern England. The annual variation in date of first emergence at Strathpeffer is itself considerable, making conclusions difficult. There is some evidence to suggest that three of the four species of *Bombus* studied in Strathpeffer are subject to a shorter effective season, as measured by the period during which workers are active, than the same species farther south in England, and that in the north-west of Scotland the season may be even more restricted. There is also a suggestion that *B. hortorum* colonies may take distinctly longer to mature than in the south. In comparing length of seasons, the extreme records (first and last individuals seen) may not give the best

comparison, since true first dates are difficult to detect and may in any case reflect exceptional individual behaviour or environmental factors, and relatively few bees are active in the first few weeks. It is at least objective, and without intensive study beyond the scope of the present work, there is little alternative.

It is tempting to conclude that the differences between north and south are related to climate, spring starting later in the north and autumn earlier, with generally lower summer temperatures. If this is the case, which Williams (1986) advances in respect of the European distribution of some southern species, then it is not consistent with the comparison between Strathpeffer and Coigach, the latter enjoying a milder winter, earlier spring, and somewhat greater spring insolation (Hay, 1982; Meteorological Office, 1989). These conditions would suggest that the active season should be earlier, not distinctly later, in Coigach. I would suggest that an additional factor determining the differences between N.E. and N.W. Scotland is the supply of forage in the N.W. in spring and early summer, and I come back to this idea later.

Forage of Bumble-bees in North Scotland

General comparisons of the forage range and character of bumble-bees at Strathpeffer confirm what has been found by other workers (e.g. Brian, 1957; Teräs, 1976; Fussell and Corbet, 1992), for example the tendency for trees and pollen flowers to feature in the forage of *B. lucorum*; for *pratorum* to feed at drooping blooms; and for zygomorphic blooms to feature strongly in the lists for the long-tongued *hortorum* and *pascuorum*. Zygomorphy is strongly associated with sideways orientation (90%, 36/40, of the zygomorphic blooms in my lists were also sideways oriented; see also Proctor and Yeo, 1973) and data in Barrow and Pickard (1985) suggest that it is also associated with somewhat longer corolla lengths. Prys-Jones (1982) found that *hortorum* and *pascuorum* mainly visited flowers with entrances pointing horizontally. These findings may be mere restatements of the long-established relationship between tongue length and flower depth (e.g. Brian, 1957).

There was a greater representation of woody plants (38%) than in the lists given by Barrow (1983) and Fussell and Corbet (1993), but this may be more a reflection of differing plant communities in the study areas than any fundamental difference in bee behaviour. Many of the plants have been recorded as prominent for the same bee species in earlier studies (*loc. cit.*, Brian, 1951 and 1954), despite major differences in location and the available forage. Notable recurrent associations are *Rubus* and *Ribes* spp. with *pratorum; Trifolium pratense, Digitalis, Vicia sepium, V. faba, Lonicera, Nepeta* and *Salvia* with *hortorum;*

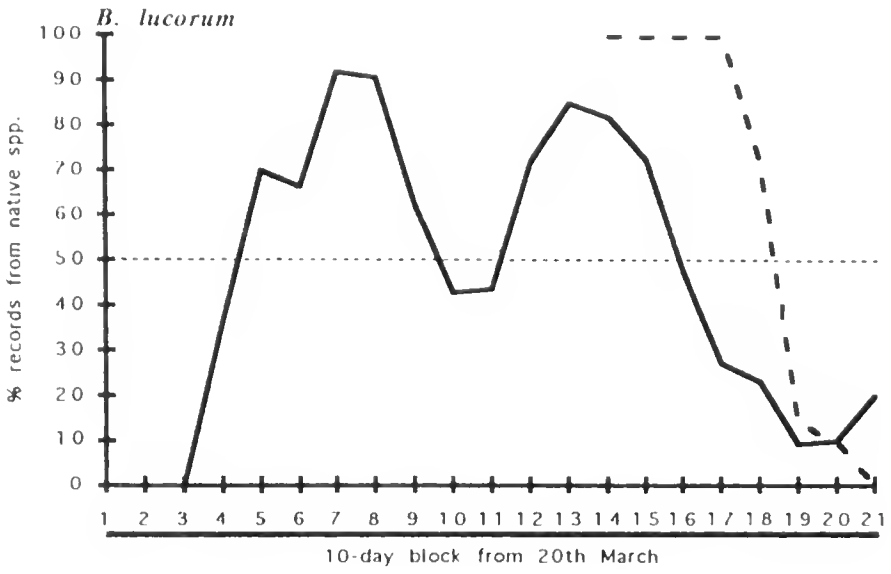
Figure 11

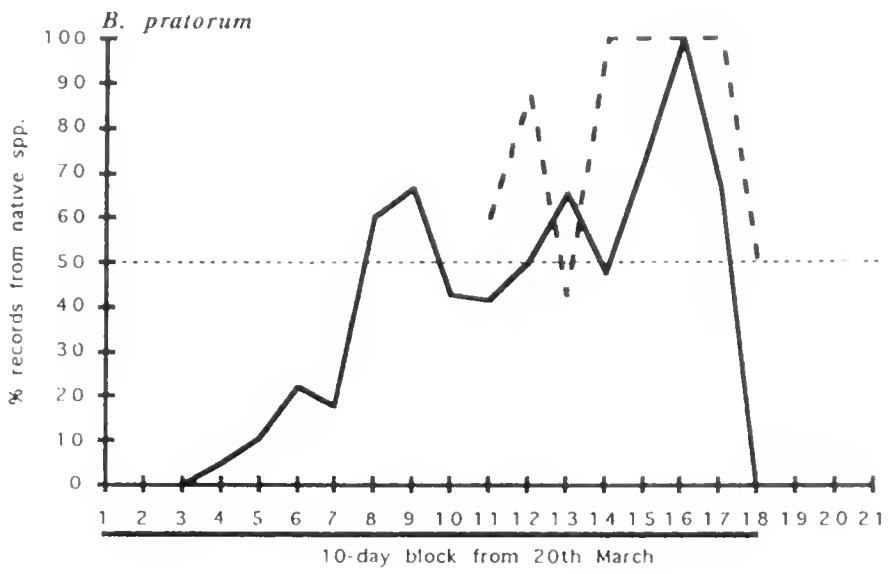
Seasonal Variation in Reliance on Native Forage of the Five Bees at Strathpeffer, 1997

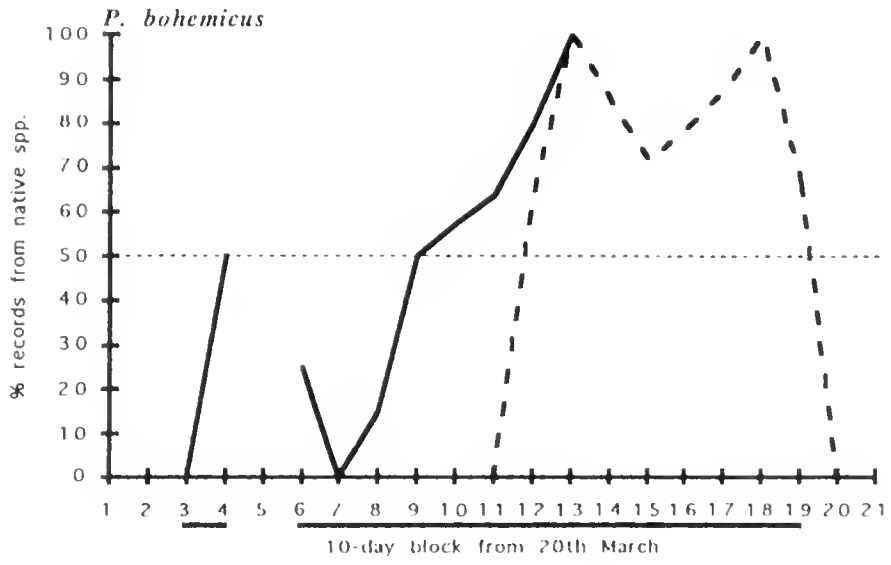
Solid lines = females; dashed lines = males.

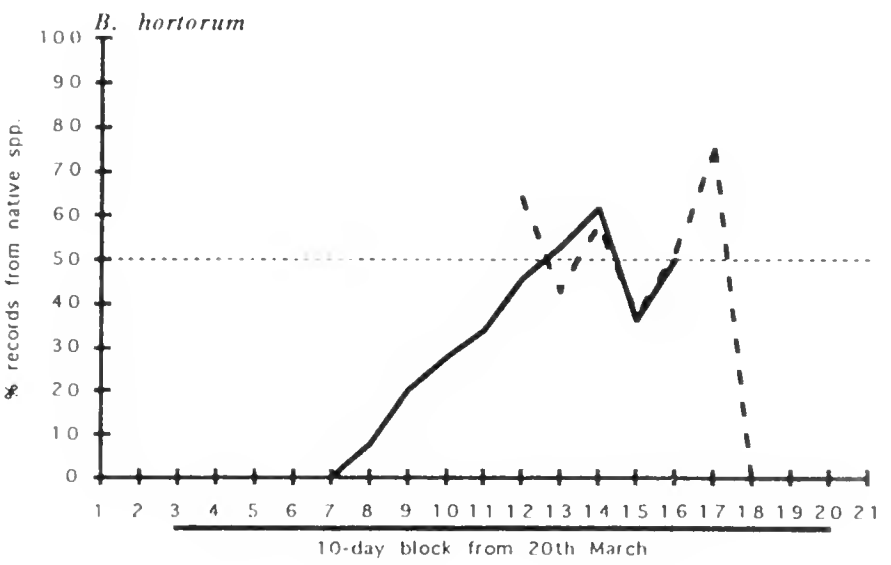
The approximate match of blocks to months is shown on the separate scale.

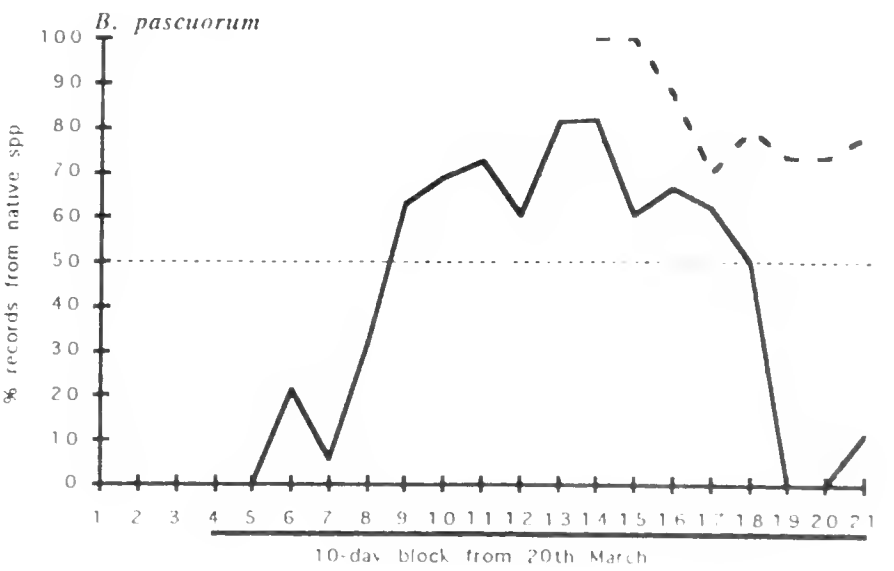
Solid lines on the X axes indicate overall periods of activity to allow distinction between zero values and absence.











Approximate conversion of blocks to months.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
M	.	.	A	.	.	.	.	.	M	.	.	.	.	.	J	.	.	.	.	.	J	.	.	.	.	.	A	.	.	.	.	.	S	.	.	.	.	.	O	.	.

Vicia sepium, V. cracca, Lathyrus pratensis, Trifolium pratense, and various Lamiaceae with *pascuorum.* In light of this, it may be worth considering whether individual bee species are more dependent on particular plant species than is usually recognised; see Prys-Jones and Corbet (1987) on *B. monticola* and *Vaccinium.*

The individual food preferences of the five species can be seen in Table 3 and Figures 6-10, but it is worth highlighting those species which seem of especial importance to the bees in general. These include *Pulmonaria* spp. and *Ribes sanguineum* in spring; *Rubus idaeus, R. fruticosus, Chamerion angustifolium* and *Cirsium vulgare* in summer; and *C. vulgare, Borago officinalis* and *Aconitum japonicum* at the end of the season.

Diversity of Diet, and Interspecific Comparisons

At any one time during the season each species of bee used a relatively small number of forage plants. Typically no more than four plant species contributed 75% of records for females in each 10-day block except (for some bees) in July and August, though the identity of the forage plants naturally changed as the season progressed. Male diets were in general less diverse than that of their females. Previous work suggests that the long-tongued *hortorum* and *pascuorum* are more specialised than the short-tongued species *lucorum* and *pratorum,* and tend to feed at flowers whose nectar is relatively inaccessible to other bees. *B. pratorum* in contrast has been recorded as feeding not only at shallow flowers, but also, as a benefit of its small size allowing it to insert its head and body into tubes, at some deeper ones (Barrow and Pickard, 1985; Prys-Jones and Corbet, 1987). It is at first sight unexpected that *pratorum* females had the least diverse diet. However, it is clear that the body size of the bee will also influence the range of forage used as highly variable body size will allow different individuals to exploit efficiently the resources held in different corolla lengths (Barrow and Pickard, 1985). It may be significant here that the variability in body size of workers and queens is much greater in the two long-tongued species than in *B. pratorum.*

The importance of tongue-length of females in determining forage choice is supported by the overlap in forage use, where the two long-tongued species at R_0=0.67, and the two short-tongued *Bombus* at R_0=0.69 formed the most similar pairings. Among females, *Psithyrus bohemicus* had the most distinct diet with almost half of the plants in its core list not shared with others. The reasons for the male groupings are not clear. Teräs (1976) provided data on the diet of male bumble-bees and their tongue-lengths, but found no correlation between them. Bertsch (1984) has considered the foraging strategy of male *B. lucorum* and *B.*

Figure 12. Overall Phenology of Use of *Symphoricarpos albus* by Four *Bombus* Species at Strathpeffer in 1997.

terrestris and concluded that it is very different from that of females and geared to their habit of spending much of the day in flight, while Prys-Jones (1982) has shown differences in flower use between males and their conspecific workers. The behaviour of males may be significant in the unexpected associations shown here, which deserve further attention.

In regard to the differences between *Bombus* and *Apis* on *Symphoricarpos* and *Tilia*, Corbet *et al.* (1995) explored the theoretical aspects of interspecific competition, and found diurnal variations in their foraging at *Cotoneaster horizontalis* very similar to the longer-term variation shown here on *Symphoricarpos.* Corbet, Unwin and Prys-Jones (1979) mention possible effects of nectar concentration on foraging by *Bombus* and *Apis* on *Tilia* which may be relevant. The present observations would be consistent with the idea that the attractiveness of the flowers to bees was reduced by the foraging of the other insects, but it is equally credible that *Symphoricarpos* was not a favoured food of bees anyway, and was used only in a 'hungry gap', and that *Tilia* quickly became suboptimal forage for *Bombus* (irrespective of other insect activity) but not for *Apis.* The problem is complicated by the changes in both available forage plants and structure of the bee populations, and a lack of information on the relative rewards offered by different plants in the study area.

The Importance of Exotic Forage

All five species of bee relied heavily on the presence of exotic forage plants at least at the beginning of the season, during the phase of colony establishment. Several authors have shown that bumble-bees forage in a way that at least strives towards the optimal (e.g. Whitham, 1974; Heinrich, 1976; Pyke, 1980; Hodges, 1981; Hodges and Wolf, 1981; Bertsch, 1984; Corbet *et al.* 1995; with cautionary comments in Heinrich, 1983). It may be assumed that the forage plants chosen by the bees in this study provide the most rewarding available, and that in the early part of the season the dearth of native forage forced the bees to use exotic species. Their importance at that stage is obvious: without them the bees' season, already short compared with farther south, would be even further restricted. An area devoid of exotic food sources at Eriboll on the north coast of Scotland has been studied by Hewson (1990). There, *Bombus lucorum* (including *magnus*) used only six food plants, with the first (*Salix* spp.) beginning to flower in mid-April and providing forage for the emerging queens. Large scale foraging by workers did not take place until *Iris pseudacorus* came into flower in early June, and *Erica* spp. even later. This corresponds to a delay of 3-4 weeks compared with Strathpeffer in 1997, similar to the season at Coigach. Later, and especially during June and July, in the peak of colony activity and of native plant flowering, use of exotic

species must be by choice based either on intrinsic value to the bees of the flowers, or by virtue of the high local density of exotic blooms in the garden cutting down travelling time between flowers. The findings of Williams (1989) linking diversity of bumble-bees to the density of suitable forage are relevant here.

It is possible to speculate in general terms on the significance of exotic forage to bees in the Highlands. At one extreme the bees might be unable to exist without them. This has been suggested for *B. hortorum* in Iceland by Prys-Jones *et al.* (1981). This clearly does not apply here, even for *hortorum*, as apparently self-sustaining populations breed in Coigach and elsewhere in the west in the absence of any significant early exotic plants, and were able to forage in summer on native plants such as *Cirsium vulgare* and *Stachys palustris*. *B. hortorum* in western sites, however, does forage intensively at the exotic *Fuchsia magellanica* which, in these relatively frost-free areas, is commonly planted as a hedge (personal observation in mainland west Scotland, and on the islands of South Uist and Harris). It is possible that detailed research would show that *Fuchsia* is crucial to its success in these parts.

More probably, the provision of exotic forage affects the density and/or productivity of colonies. The extension permitted to the season in spring, and possibly also in late summer and autumn, is likely to extend overall colony life by up to 10-30% depending on species, and, given that exotic forage is used significantly throughout the summer, to guarantee an abundant supply of nectar and pollen for provisioning the active colonies. Exotic forage was important even during September and October for *lucorum* and *pascuorum* males and for queens fattening up for hibernation. This might have important consequences, both for the fecundity and winter survival of the queens.

The five species studied here differed in their use of exotic plants. If such native flowers as were present but ignored in spring and autumn are genuinely unsuitable for sustaining colony activity, as is suggested by observations in the west, and assuming that all species could extend their activity to mid-October at the latest, the data (see Table 1, Figures 6-10) indicate that without exotic forage available at Strathpeffer the consequences would be as follows.

B. lucorum would lose 35 days in spring, though this would be less in the years when *Salix caprea* was utilised. I have no data on how frequently this happens. Its season would be reduced by 17%, with consequent effects on colony productivity, but the cycle could be completed before mid-October. *B. pratorum* would lose 34 days in spring. Its season would be reduced by 20% but the colony cycle could be completed. This species is the least widespread in the Highlands of

the *Bombus* considered here, being very scarce on the west coast (Alford, 1980; Macdonald, 1998), and this may suggest that here it is more dependent on exotic forage than the others. It generally emerges early in Britain and has a short season (Free and Butler, 1959; Prys-Jones and Corbet, 1987), and may therefore be particularly reliant on early spring forage for successful breeding. Activity of these two earliest-emerging species may sometimes be limited by poor weather rather than by availability of forage in March and early April, decreasing in some years the advantage provided by exotic forage. Any individual advantage would obviously be less, the later that individual queens emerged.

B. hortorum would lose 50 days at the beginning of the season, and its season would be reduced by 29%, but, given its heavy use of exotic forage for virtually the whole summer, it seems certain that lack of food would affect productivity significantly. A delay of 50 days in the start of its active season would seriously limit the time for males and new queens. *B. pascuorum* would lose 14 days at the beginning of the season, and 30 days at the end, reducing its season by 46%, but this would still allow the colony to run to completion. Some of the contrast between this species and *hortorum* stems from the longer active season of *pascuorum* workers (128 days compared with 91 days in *hortorum*), and the fact that *pascuorum* workers are able to remain active well into October while *hortorum* workers were not seen after the end of August.

P. bohemicus would lose 12 days at the beginning of the season, but with only three records from native plants out of 19 (16%) in the first 44 days this may underestimate the effect. It would then have native forage available until the end. Its season would be reduced by 8% (up to 28%?). Despite this, it would be able to complete its cycle and fit in with a delayed *lucorum* (its host). Like *B. pratorum*, it is virtually absent on the west coast (Alford, 1980; Macdonald, 1998) and the females at Strathpeffer relied heavily on exotic forage, so it is possible that its distribution too is related to a lack of spring forage in the west.

It is probably unlikely that the effects would be quite as simple as this, and more credibly the bees would, to some extent, move to native species allowing less efficient foraging, that the reduction in length of season would be less than suggested, and that the effects would impact more on colony size. Even by mid-April, however, the only potential native forage available at Strathpeffer after the *Salix* catkins had passed was *Bellis perennis*, *Taraxacum vulgaris* agg. and *Ranunculus ficaria*. Of these I recorded only *Taraxacum* as core forage, and only *R. ficaria* (on which, as with its congeners, I have never seen bumble-bees forage) seemed to occur in sufficient density to be considered as a possible viable alternative. It seems certain that in some years at least, the availability of exotic

forage in spring will allow an early start for colony establishment, if only because that will provide the only suitable food available to early emerging queens.

If exotic forage is potentially of such importance to bumble-bees, it will clearly influence their distribution. There is a casual tendency to dismiss the absence of certain species from the north of Scotland by reference to the cold wet climate. This is not sustainable on examination of the evidence (Meteorological Office, 1989) which goes some way to debunking the popular view of the Scottish climate, although summer temperatures have been linked with the northern limit of distribution of some southern *Bombus* by Williams (1986). On the more local scale within the Highlands it seems unavoidable that the lower availability or absence of exotic garden plants in the north and west Highlands, as compared with farther south and east, must be taken into account in considering the distribution of the widespread bumble-bees studied here, and very likely of other insects also. As indicated above, *B. pratorum* may be most relevant here. For the others, observers should be aware that in parts of north and west Scotland the paucity of exotic forage may force a later season, lower density, and more patchy dispersion of bees than elsewhere, and that short surveys even in high summer may fail to detect their presence. The rarer species of northern Scotland - *soroeensis, monticola, jonellus, muscorum* and *distinguendus* - are not usually associated with gardens and their seasonality and distribution are presumably governed by other factors.

Finally, the results emphasise the importance of gardens to native insects (*cf.* Owen and Owen, 1975). The overall performance of the bee populations was undoubtedly enhanced by the availability of appropriate exotic garden flowers at Strathpeffer, and that must be an indicator of their more general effects on anthophagous insects. This aspect, with the emphasis on 'appropriate', should not be overlooked in programs which encourage the establishment of native plant species in gardens in order to attract wildlife, and might compensate for the fact that some highly modified cultivars are of little use as bee forage (Fussell and Corbet, 1993; Vines, 1997).

Summary

The seasonal activity of, and forage use by, five bumble-bees in the genera *Bombus* and *Psithyrus* were studied during 1997 at one site in north Scotland where the active season tends to be shorter than farther south in Britain. Native forage was scarce at the beginning and end of the season and all bees relied on exotic garden plants for some time, permitting an earlier start to colony establishment than only native forage would have allowed. Exotic forage was used

Appendix 1

Details of the 10-day Blocks Used in the Analysis of Bee Activity and Diet

Block:	1	2	3	4	5	6	7	8	9	10	11
start date	20/3	30/3	9/4	19/4	29/4	9/5	19/5	29/5	8/6	18/6	28/6
end date	29/3	8/4	18/4	28/4	8/5	18/5	28/5	7/6	17/6	27/6	7/7
days observation	10	6	7	10	10	10	9	10	10	10	10

Block:	12	13	14	15	16	17	18	19	20	21
start date	8/7	18/7	28/7	7/8	17/8	27/8	6/9	16/9	26/9	6/10
end date	17/7	27/7	6/8	16/8	26/8	5/9	15/9	25/9	5/10	15/10
days observation	8	10	7	9	9	10	10	9	10	10

Appendix 2

(Pages 100 and 101)

English Names of Plants Mentioned in the Text

A: Recorded as forage at Strathpeffer, 1997.

B: Available at Strathpeffer but not recorded as forage (this should not be regarded as exhaustive). See comments on *Salix caprea* in the text.

C: Other plants mentioned in text.

*Native or naturalised.

°Non-core forage (A only).

A: Recorded as forage

Acer pseudoplatanus Sycamore*
Aconitum japonicum Monk's-hood
Aconitum x *cammarum* Hybrid Monk's-hood
Aesculus hippocastanum Horse-chestnut*
Ajuga purpurea Bugle
Ajuga reptans Bugle*
Allium schoenoprasum Chives°
Alyssum saxatile Golden Alison°
Angelica sylvestris Wild Angelica°*
Aquilegia sp. Columbine°
Arctium minus Lesser Burdock*
Armeria maritima Thrift
Aster novi-belgii Confused Michaelmas-daisy°
Astrantia major Astrantia
Azalea sp. Azalea°
Bergenia cordifolia Elephant-ears°
Borago officinalis Borage
Buddleja davidii Butterfly-bush
Calluna vulgaris Heather*
Calystegia sepium Hedge Bindweed°*
Calystegia silvatica Large Bindweed*
Campanula latifolia Giant Bellflower
Centaurea macrocephala Great Golden Knapweed°
Centaurea montana Perennial Cornflower
Chamerion angustifolium Rosebay Willowherb*
Cirsium arvense Creeping Thistle*
Cirsium palustre Marsh Thistle*
Cirsium vulgare Spear Thistle*
Consolida sp. Larkspur°
Cotoneaster sp. (erect) Cotoneaster°
Cotoneaster sp. (prostrate) Cotoneaster
Cytisus scoparius Broom*
Dactylorhiza purpurella Northern Marsh-orchid°*
Dicentra formosa Bleeding-heart°
Digitalis purpurea Foxglove*
Epilobium montanum Broad-leaved Willowherb°*
Erica carnea Winter-flowering Heath
Erica cinerea Bell Heather*
Erica tetralix Cross-leaved Heath*
Erica vagans Cornish Heath°
Erysimum sp. Wallflower
Euphorbia esula Leafy Spurge°
Filipendula ulmaria Meadowsweet*
Fragaria x *ananassa* Garden Strawberry
Fuchsia x Fuchsia°
Geranium ?x *monacense* Munich Crane's-bill°
Geranium ?x *oxonianum*
Geranium sp
Geum borisii Avens
Hebe sp. Hedge Veronica
Helianthemum sp. Rockrose
Hyacinthoides non-scripta Bluebell°*
Hypericum pseudohenryi Irish Tutsan
Hypericum pulchrum Slender St John's-wort°*
Hypochaeris radicata Cat's-ear°*
Kniphofia praecox Greater Red-hot-poker°
Lamiastrum galeobdolon Yellow Archangel
Lamium purpureum Red Dead-nettle*

B: Available, but not recorded as forage

Achillea millefolium Yarrow*
Aegopodium podagraria Ground-elder*
Allium sp. Ornamental Onion
Anthriscus sylvestris Cow Parsley*
Bellis perennis Daisy*
Caltha palustris Marsh-marigold*
Cerastium tomentosum Snow-in-summer
Chaenomeles japonica Quince
Crataegus monogyna Hawthorn*
Crepis capillaris Smooth Hawk's-beard*
Crocosmia paniculata Aunt-Eliza
Crocosmia x *crocosmiifolia* Montbretia
Kerria japonica Kerria
Leucanthemum vulgare Oxeye Daisy*
Lithospermum sp. Lithospermum
Lysimachia nummularia Creeping Jenny
Lysimachia vulgaris Yellow Loosestrife
Mentha spicata Spear Mint
Menyanthes trifoliata Bogbean*
Myrrhis odorata Sweet Cicely*
Narcissus spp. Daffodils
Oxalis adenophylla Wood-sorrel
Paeonia sp. Peony
Phlox paniculata Phlox
Pisum sativum Garden Pea
Potentilla erecta Tormentil*

C: Other plants mentioned

Alliaria petiolata Garlic Mustard*
Alnus glutinosa Alder*
Anemone nemorosa Wood Anemone*
Anthriscus sylvestris Cow Parsley*
Aruncus dioicus Buck's-beard
Cardamine pratensis Cuckooflower*
Centaurea nigra Common Knapweed*
Fuchsia magellanica Fuchsia

Lathyrus pratensis Meadow Vetchling*
Lavandula x *intermedia* Garden Lavender
Levisticum officinale Lovage
Lonicera periclymenum Honeysuckle*
Lotus corniculatus Common Bird's-foot-trefoil°*
Lupinus x *regalis* Russell Lupin
Lychnis flos-cuculi Ragged-robin°*
Malus domestica Apple
Meconopsis cambrica Welsh Poppy
Meconopsis sp. Meconopsis°
Mimulus luteus Blood-drop-emlets°
Nepeta x *faassenii* Garden Catmint
Origanum majorana Pot Marjoram°
Pelargonium zonale Geranium
Pieris forrestii Lily-of-the-Valley Bush
Polygonatum x *hybridum* Garden Solomon's-seal°
Polygonum bistorta Bistort
Potentilla fruticosa Shrubby Cinquefoil
Primula pulverulenta Candelabra Primula°
Primula x *polyantha* Polyanthus
Prunella vulgaris Selfheal°*
Prunus avium Wild Cherry*
Prunus serrulata Japanese Cherry
Pulmonaria spp. Lungwort
Rhododendron ponticum Rhododendron
Rhododendron sp. Rhododendron (3 forms)
Ribes nigrum Black Currant
Ribes sanguineum Flowering Currant
Rosa canina Dog-rose*
Rosa rugosa Japanese Rose
Rosa sp. Garden Rose°
Rosmarinus officinalis Rosemary°
Rubus fruticosus agg. Bramble*
Rubus idaeus Raspberry*
Salvia officinalis Sage
Sedum rupestre Reflexed Stonecrop°
Sedum spectabile Butterfly Stonecrop
Sedum spurium Caucasian-stonecrop
Senecio jacobaea Common Ragwort°
Sidalcea sp. Greek Mallow°
Spiraea x *arguta* Bridal-spray
Stachys byzantina Lamb's-ear
Stachys sylvatica Hedge Woundwort*
Symphoricarpos albus Snowberry
Symphoricarpos x *chenaultii* Pink Snowberry
Taraxacum sp. Dandelion*
Thermopsis montana False Lupin°
Thymus polytrichus Wild Thyme
Tilia x *vulgaris* Lime*
Trifolium pratense Red Clover*
Trifolium repens White Clover*
Ulex europaeus Gorse*
Vicia cracca Tufted Vetch*
Vicia faba Broad Bean
Vicia sepium Bush Vetch*
Viola x Pansy

Prunus domestica Plum
Prunus padus Bird Cherry*
Pyrus sp. Pear
Ranunculus acris Meadow Buttercup*
Ranunculus ficaria Lesser Celandine*
Ranunculus flammula Lesser Spearwort*
Ranunculus repens Creeping Buttercup*
Rhododendron sp. Azalea
Salix caprea Goat Willow*
Salix spp. Ornamental Willow
Saxifraga sp. Mossy Saxifrage
Saxifraga x *urbium* Londonpride
Sedum rosea Roseroot
Silene dioica Red Campion*
Silene latifolia White Campion*
Silene latifolia x *dioica**
Sonchus asper Prickly Sow-thistle*
Sorbus aucuparia Rowan*
Spiraea x *pseudosalicifolia* Confused Bridewort
Stellaria graminea Lesser Stitchwort*
Stellaria holostea Greater Stitchwort*
Symphytum tuberosum Tuberous Comfrey
Tulipa gesneriana Garden Tulip

Iris pseudacorus Yellow Iris*
Oxalis acetosella Wood-sorrel*
Primula vulgaris Primrose*
Salix aurita Eared Willow*
Stachys palustris Marsh Woundwort*
Viola riviniana Common Dog-violet

by the females of all species (especially *B. hortorum*) for much of the summer. *B. pascuorum* females also relied on exotic plants at the end of the summer. Interspecific overlap in diet of females may reflect similarities in tongue length, but that of males has no obvious correlation. Males tended to have a less diverse diet than their females, and *B. pratorum* in particular maintained a relatively restricted diet throughout the year. It is suggested that the availability of exotic forage, especially in gardens in spring, is an important factor affecting the abundance and distribution of bumble-bees in much of northern Scotland.

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EXCEPTIONALLY LARGE FOX AT FINTRY, WEST STIRLINGSHIRE

By JOHN MITCHELL
Drymen, Stirlingshire

In January 1998, a male Red Fox *Vulpes vulpes* was shot in the act of stalking a young Roe Deer *Capreolus capreolus* in Dungoil Plantation near Fintry, West Stirlingshire. According to the gamekeeper who killed the beast, it was by far the heaviest hill Fox he had come across in a lifetime's experience, weighing in at 27 lb / 12.25 kg (Plate 1, page 106; photograph by Mr. John B. Mason).

Well-fed town Foxes of this size are not unknown according to zoologist-taxidermist Mr. Allan Allison (personal communcation), but the figure is well in excess of the top weight of around 22 lb / 10 kg for a full-grown dog Fox living in the wild (Van den Brink, 1967).

Perhaps it is just coincidental, but since this outsize animal met its end, there appear to have been no further sightings reported of a so-called 'big cat' lurking around the Fintry area (see *Sunday Mail* 25th May 1997 and *Stirling Observer* 30th May 1997).

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Plate 1

The Fintry Fox

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CONTENTS

1998 - Part 2

The Feeding Ecology of some *Bombus* and *Psithyrus* Bumble-Bees (Hym., Apidae) in Northern Scotland
By Dr. Murdo A. Macdonald 51-104

Exceptionally Large Fox at Fintry, West Stirlingshire
By Mr. John Mitchell 105-106

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